RADAR PROPAGATION AND BACKSCATTERING PREDICTIONS FOR A CODAR SYSTEM OPERATING IN BRACKISH WATERS

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C-CORE

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TABLE OF CONTENTS

		PAGE
Acknowledgements		i
Table of Contents		iii
List of Figures and Tables		v
1.0	Introduction	1
2.0	Transmission Loss Theory (Flat Earth Model)	3
	2.1 Propagation of a Vertically Polarized E/M Wave Over Horizontally Homogeneous Media	3
	2.2 Transmission Loss	5
	2.3 Vertical Infinitesimal Dipoles	6
3.0	Model Adapted for Computation	9
	3.1 Calculation of Normalized Surface Impedance	9
	3.2 Evaluating F(w)	10
4.0	Transmission Loss; Modelled (Flat Earth) vs. Observed Contribution from Surface Roughness	13
	4.1 Contribution of Surface Roughness and Curvature to Transmission Loss Over Sea Water.	13
5.0	Definition of Performance of CODAR: Incorporating Effect of Surface Roughness	21
	5.1 CODAR: Simplified Description	21
	5.2 Fourier Transform	23
	5.3 Maximum Range	25
6.0	Electrical Properties; Sea Water. Brackish Water	31
	6.1 Complex Permittivity	31
	6.2 Relating ϵ_r, σ to Salinity	31
7.0	Predicted CODAR Range Over Brackish Water	37
	7.1 CODAR Range Over Brackish Water: Maximum Tolerable Transmission Loss	37

8.0 Deteriation of Performance over Sea Ice 43

8.1 Excessive Transmission Loss Expected 43

9.0 Detection of Estuarine Fronts: An Example 45

9.1 Detection of the Boundary 45

9.2 Theory 46

9.3 Modelling the Plume of the Saguenay and the Surrounding St. Lawrence 51

9.4 Calculated Radar Cross-section of Plume Boundary 51

9.5 Calculation of Transmission Loss With Plume Present 54

10.0 Specific Areas of Interest: Projected Performance, Operational Considerations 57

10.1 Seasonal Ice Coverage 57

10.2 Preferred Arctic Location for Survey 58

10.3 Projected Performance: East Entrance to Bellot Strait 63

10.4 Region of St. Lawrence near Outlet of Saguenay: Projected Performance 63

11.0 Summary 67

References 69

APPENDIX A Program Listing Computerized Transmission Loss Model 71

APPENDIX B Tabulated One Way Path Loss Versus Range for Brackish Water 83

APPENDIX C Statement of Work for Contract 123

LIST OF FIGURES AND TABLES

		PAGE
Figure 1	Geometry for Transmission Loss Model	4
Figure 2	Calculated Transmission Loss Over Sea Water (Flat Earth) versus Transmission Loss Measurements	16
Figure 3	Radial Geometry of the CODAR System	19
Figure 4	Radial Surface Current Map	22
Figure 5	Relative Power Doppler Spectrum	24
Figure 6	Relative Power Doppler Spectrum	26
Figure 7	Relative Power Doppler Spectrum	28
Figure 8	One Way Transmission Loss Over Brackish Water ...	40
Figure 9	One Way Transmission Loss Over Brackish Water ...	41
Figure 10	One Way Transmission Loss Over Brackish Water ...	42
Figure 11	Transmission Loss Over Sea Ice	44
Figure 12	Model of Plume and Surrounding Water at Ebb Tide	47
Figure 13	Geometry for Evaluation of "G"	49
Figure 14	Considerations of Radar Location	60
Figure 15	Suggested CODAR station Locations for Survey of East Entrance to Bellot Strait	62
Figure 16	Suggested CODAR Station Locations for Survey of Saguenay Entering St. Lawrence	66
Table 1	Transmission Loss (flat earth) vs Transmission Loss (spherical earth)	15
Table 2	Apparent Added Loss due to Sea State vs. Range ..	18
Table 3	Maximum Range vs. Wind Speed	29
Table 4	Calculated ϵ_r, σ vs Salinity and Temperature ...	36
Table 5	One Way. Two Way Tolerable Transmission Loss vs. Range	38
Table 6	$\|G\|$ vs $\|F(W)\|$	55

1.0 INTRODUCTION

CODAR (Coastal Ocean Dynamics Applications Radar) is currently being used by various agencies to map currents on the upper surface of the ocean. The radar operates in the HF band and uses coherent Doppler processing.

To date C-CORE has only used CODAR for surveys over sea water. Sea water due to its high salinity is considered a good conductor. However, if the waters surveyed were to be less saline, the effective range of CODAR would be reduced because of the reduction in conductivity.

This report, analytically predicts the change in CODAR's performance for surveys over less saline, (brackish) waters. Essentially this predicts a reduction in the range over such waters, compared with the typical range over sea water.

Once performance over brackish water is quantified, the report looks at the ability of CODAR to identity an estuarine front where the area under survey would be characterized by two salinities, inside and outside the front. Lastly three oceanographic scenarios are studied to determine the effectiveness of CODAR to map surface surrents in those areas.

The problem of general performance will be dealt with in a progressive manner.

A general model of HF propagation over a uniform flat surface will be outlined. The model will be compared with actual measurements of HF propagation over sea water. It will become apparent that the quantity of interest, transmission loss over sea water, can be separated into two components, that predicted

by the model, and a correction due to surface roughness.

This correction due to roughness will turn out to be inherent in the definition of CODAR performance. From theory this correction for surface roughness will remain relatively constant regardless of the medium's salinity.

The propagation model will then be used with the definition of CODAR performance to predict the change in performance as the medium of interest becomes less saline. For this last item equations will be taken from available literature to relate the salinity of the medium to its electrical properties, so that the model may be used.

2.0 TRANSMISSION LOSS THEORY (FLAT EARTH MODEL)

For the derivation of the particular form of the equation of the vertical electric field contained in section 2.1 see Walsh (1982). We will simply state his results and make a few comments; in Section 5.2 transmission loss is defined in a useable form.

2.1 Propagation of a Vertically Polarized E/M Wave Over Horizontally Homogeneous Media:

(See Figure 1) For an infinitesimal vertical dipole in free space, a distance h above a semi-infinite medium in the lower half space, the far field approximation to the vertical electric field E_z at $(x, y, {}^{+}z)$ is given by Walsh, (1982);

$$E_z = \frac{k^2 I d\ell}{j\omega\epsilon_0 4\pi}\left[\frac{e^{-jkR_o}}{R_o}\cos^2\phi + \cos^2\theta\left(R_v\frac{e^{-jkR_1}}{R_1} + (1-R_v)(1-\Delta^2)\,F(w)\,\frac{e^{-jkR_1}}{R_1}\right)\right] \tag{1}$$

where θ , R_o, R_1 are as defined in Figure 1,

I is the current in the dipole of length dl,

and $$k = \frac{2\pi}{\lambda}$$

R_v is the reflection coefficient at the interface between free space and the semi-infinite medium.

$$R_v = \frac{\sin\theta - \Delta}{\sin\theta + \Delta} \tag{2}$$

F(w) is the Norton attenuation function.

$$F(w) = 1 - j(\pi w)^{\frac{1}{2}}\, e^{-w}\, \text{erfc}\,(jw^{\frac{1}{2}}) \tag{3}$$

where erfc is the complementary error function,

$$w = \frac{-jkR_1\Delta^2}{2} \left(1 + \frac{z^+ + h}{\Delta R_1}\right)^2 \qquad (4)$$

and Δ = normalized surface impedance of the semi-infinite medium.

Note that when h = 0 (grazing incidence), cos θ = 1, cos ϕ = 1, R_v = -1, and

$$E_z \text{ reduces to, } \frac{k^2 I d\ell}{j\omega\epsilon_0 4\pi} \; 2\left[(1 - \Delta^2)\, F(w)\, \frac{e^{-jk\rho}}{\rho}\right] \qquad (5)$$

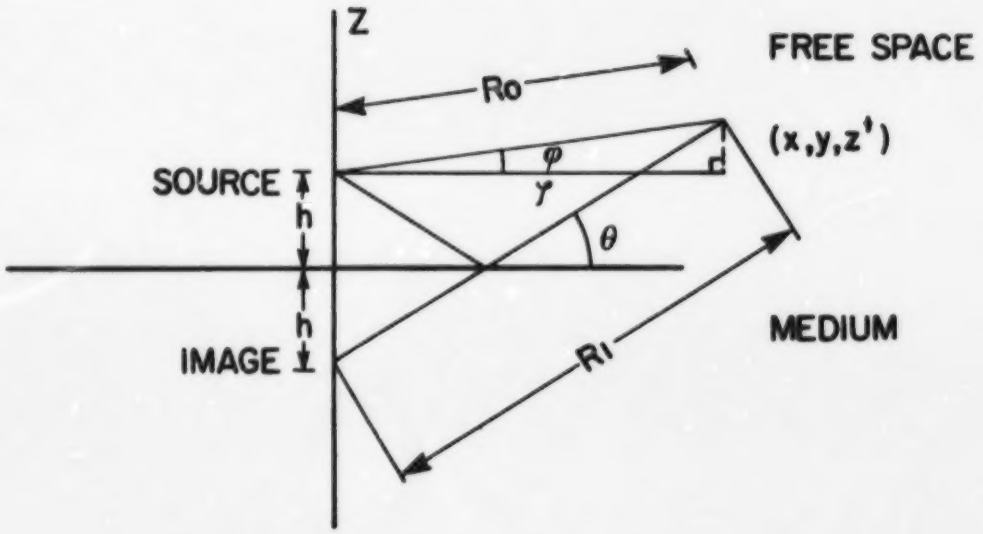


Figure 1 The medium in the lower half space is taken to be horizontally homogeneous. Its electrical properties may only vary in the vertical ( ) direction.

2.2 Transmission Loss

We must develop a form for transmission loss which will allow us to compare theoretical predictions of loss based on the formula in section 2.1 with the actual observed loss.

Consider a current source in free space and an identical source in some complex medium. The fields of the sources are measured at the same arbitrary point (away from the sources) in both systems. Then we can write,

$$\frac{\text{Loss (free space)}}{\text{Loss (complex medium)}} = \frac{\left[\dfrac{\text{Power Radiated}}{\text{Power Received}}\right]_{\text{free space}}}{\left[\dfrac{\text{Power Radiated}}{\text{Power Received}}\right]_{\text{complex medium}}} \tag{6}$$

Since the power radiated is the same in both systems this gives

$$\frac{\text{Loss}_{\text{(free space)}}}{\text{Loss}_{\text{(complex medium)}}} = \frac{(\text{Power received})_{\text{complex medium}}}{(\text{Power received})_{\text{free space}}} \tag{7}$$

Let us denote the electric field at the point of reception by E_c for the complex medium and E_o for free space.

Then, since in general power received $\alpha\, E^2$

$$\frac{\text{Loss}_{\text{(free space)}}}{\text{Loss}_{\text{(complex medium)}}} = \frac{E_c^2}{E_o^2} \tag{8}$$

$$\text{or } \text{Loss}_{(\text{complex medium})} = (E_o^2 / E_c^2)\ \text{Loss}_{(\text{free space})} \tag{9}$$

For the specific case of two antennas in free space, one being the source with a gain G_t and the other the receiving antenna with a gain G_r, the loss is given in the "Antenna Engineering Handbook", (Jasik, H. ed., 1961);

$$\text{Loss (free space)} = \left[\frac{4\pi d}{\lambda}\right] \frac{1}{G_t G_r} \tag{10}$$

Where it is assumed that the receiving antenna is in the far field and its effective area depends only on its geometry.

Then for two antennas separated by d,

$$\text{Loss}_{(\text{complex medium})} = \frac{E_o^2}{E_o^2} \left(\frac{4\pi d}{\lambda}\right)^2 \frac{1}{G_t G_r} \tag{11}$$

2.3 Vertical Infinitesimal Dipoles:

We shall now evaluate the theoretical transmission loss between two vertical infinitesimal dipoles both in free space above a complex medium (Figure 1) where the elevations of the dipoles are small compared to the distance of separation. Since the dipoles are vertical we are only concerned with the z component of the electric field.

For an infinitesimal vertical dipole in free space the vertical component of the electric field in a plane passing through the dipole axis perpendicular to the axis is (to first order), (Lorraine and Corson, (1970)),

$$E_{oz} = \frac{k^2 I d\ell}{j\omega\epsilon_0 4\pi} \cdot \frac{e^{-jkr}}{r} \quad \text{(far field)} \tag{12}$$

In our case (Figure 18, Lorraine and Corson, 1970)

$r \doteq R_o$ for $h, z^+ << R_o$

Therefore, under the following conditions,

i) vertical infinitesimal dipoles

ii) separation much greater than antenna elevations

iii) separation equivalent to the far field

$$E_o = E_{oz} \ (r = R_o), \ E_c = E_z$$

Then the theoretical transmission loss is:

$$\text{Loss} = \left[\cos^2\phi + \cos^2\phi\left(\frac{R_v R_o}{R_1} e^{-jk(R_1-R_0)} + (1-R_v)(1-\Delta^2)F(w)\frac{R_0}{R_1}e^{-jk(R_1-R_0)}\right)\right]\left(\frac{4\pi R_o}{\lambda}\right)^2 \frac{1}{G_t G_r} \tag{13}$$

In the case of glancing incidence and $\rho >> h, z^+$, $\cos^2\theta = 1$, $\cos^2\phi = 1$ and $\frac{R_o}{R_1} \doteq 1$ yielding,

$$\text{Loss} = \frac{1}{G_t G_r}\left[\frac{\lambda}{4\pi R_0}\left(1 + R_v e^{-jk(R_1 - R_0)} + (1-R_v)(1-\Delta^2)\, F(w)\, e^{-jk(R_1 - R_0)}\right)\right]^{-2} \tag{14}$$

3.0 MODEL ADAPTED FOR COMPUTATION

This section describes the software used to calculate transmission loss, based on the loss equation (14) calculated in section 2.3. The program, written in FORTRAN, has been documented with appropriate comments throughout, and is listed in Appendix A.

3.1 Calculation of Normalized Surface Impedance:

The complex medium is characterized as a series of M horizontally uniform layers above a semi-infinite medium (sea water). Layer M is the first layer above sea water and layer 1 corresponds with the surface. Associated with each layer is a triplet $(\epsilon_{rm}, \sigma_m, h_m)$ where,

ϵ_{rm} = relative permittivity of layer m,
σ_m = conductivity of layer m,
h_m = thickness of layer m

It is assumed that for all layers $\mu_m = \mu_o$.

The calculation of transmission loss requires the calculation of Δ, the normalized surface impedance of the medium in the lower half space. Based on the work of Wait. (1970) Δ is given by,

$$\Delta = \frac{Z_1}{120\pi} \qquad (15)$$

where Z_1 is calculated from the recursion relationship

$$Z_m = K_m \left(\frac{Z_{m+1} + K_m \tanh (U_m h_m)}{K_m + Z_{m+1} \tanh (U_m h_m)} \right) \quad (16)$$

and,

$$K_m = \frac{U_m}{\sigma_m + j\omega\varepsilon_{rm}\varepsilon_0} \quad (17)$$

$$U_m = \sqrt{K_0^2 + \gamma_m^2} \quad (18)$$

$$\gamma_m = j\sigma_m\mu_m\omega - \varepsilon_{rm}\varepsilon_0\mu_m\omega^2 \quad (19)$$

$$K_0^2 = \omega^2\varepsilon_0\mu_0 \quad (20)$$

In this particular form Δ represents the normalized surface for a plane wave at grazing incidence to the complex medium.

To calculate Z_1 the program must iterate Z_m upwards from the semi-infinite medium, requiring the properties of the layers to be read initially with the lowest layer above sea water.

3.2 Evaluating F(w)

The calculation of transmission loss also requires evaluation of the Norton Attenuation function F (w); (see Section 2.1).

From the work of Wait. (1970) the method of evaluating F(w) is determined by the values of the magnitude and argument of w written in the form

$$w = |w|e^{jb} \quad (21)$$

when $|w| < 10$ a convergent series expansion is used,

$$F(w) \doteq 1 - j\sqrt{\pi w}\, e^{-w} - 2w + \frac{(2w)^2}{1x3} - \frac{(2w)^3}{1x3x5} + \ldots \qquad (22)$$

For $|w| > 10$ two asymptotic expansions based on the argument of w are used;

$|w| > 10$ and $-2\pi < b < 0$

$$F(w) \doteq \frac{1}{2w} - \frac{1x3}{(2w)^2} - \frac{1x3x5}{(2w)^3} \qquad (23)$$

$|w| > 10$ and $0 < b < 2\pi$

$$F(w) = -2j\sqrt{\pi w}\, e^{-w} - \frac{1}{2w} - \frac{1x3}{(2w)^2} - \frac{1x3x5}{(2w)^3} - \ldots \qquad (24)$$

4.0 TRANSMISSION LOSS; MODELLED (FLAT EARTH) vs. OBSERVED CONTRIBUTION FROM SURFACE ROUGHNESS

This section lists the results of transmission loss measurements over sea water at the operating frequency of CODAR. Using wind data recorded at the time of measurement it will be shown that the flat earth propagation model is in general agreement with the observed loss data once surface roughness of the ocean is taken into account.

4.1 Contribution of Surface Roughness and Curvature to Transmission Loss Over Sea Water

The surface of the electrically homogeneous medium over which an Electromagnetic wave is propagated may be modelled in several manners.

The four popular choices, in increasing order of complexity, are:

1) Flat Earth: The lower medium is an infinite, smooth, flat slab with homogeneous electrical properties. The upper medium is approximated by free space. In this case the Norton Surface Wave Solution as approximated by Wait (1970) is used to calculate an attenuation function.

2) Flat Earth with Surface Roughness: As with smooth flat earth except the surface is no longer smooth. The roughness is treated in a statistical manner as a modification to the surface impedance, (eg. Barrick, 1970, 1971 and Srivastava, 1984).

3) Spherical Smooth Earth: The effects of the earth's curvature are considered. The model is based on the work of Fock (1945), Bremmer (1949) and Wait (1970).

4) Spherical Earth with Surface Roughness: As with spherical smooth earth with a modified surface impedance to account for surface roughness. (Again, Barrick, 1970, 1971 and Srivastava 1984)

Consideration will first be given to the difference in transmission loss over sea water when calculated with the flat earth model versus the smooth spherical earth model. This is tantamount to comparing the Norton Attenuation Function, $|F|$, with the spherical earth attenuation function, $|W|$.

In the case of an operating frequency in the CODAR range, 25.4 MHz zero height for transmit and receive antennas, a relative permittivity of 80 and a conductivity of 4 mhos/m representing sea water, the results in Table I were obtained using the flat earth model described in sections 2, 3 and the spherical smooth earth model implemented by Barry Dawe (Ocean Engineering Group, Memorial University):

Comparison indicates that while the flat earth model will calculate less loss than spherical smooth earth, the difference is small within a range of 45 km. Bearing in mind the range of CODAR for surface current mapping, the effect of the earth's curvature will be ignored.

TABLE 1 Transmission Loss (flat earth) vs.
Transmission Loss (spherical earth

Range (km)	$\|F\|^*$ Flatearth	$\|W\|^*$ Spherical Smooth earth
5	0.80	0.80
10	0.65	0.65
15	0.54	0.53
20	0.45	0.43
25	0.37	0.36
30	0.32	0.30
35	0.27	0.25
40	0.23	0.21
45	0.20	0.17

* (rounded to two significant digits)

The effect of surface roughness, however, cannot be neglected (Barrick, 1971). Fortunately, Barrick (1970, 1971) has calculated the additional loss in dB due to sea state (ie. roughness) over the loss associated with smooth spherical earth for sea water, for a number of frequencies and sea conditions using a Philips semi-isotropic wind-wave spectrum. Barrick (1971) has also calculated effective surface impedances (used in the transmission loss calculation) based on a Neumann-Pierson spectrum modified with a cosine squared directionality in order to examine the effect of wind direction. His calculations show a significant difference in the effective surface impedance depending on the wind direction at HF frequencies, which will

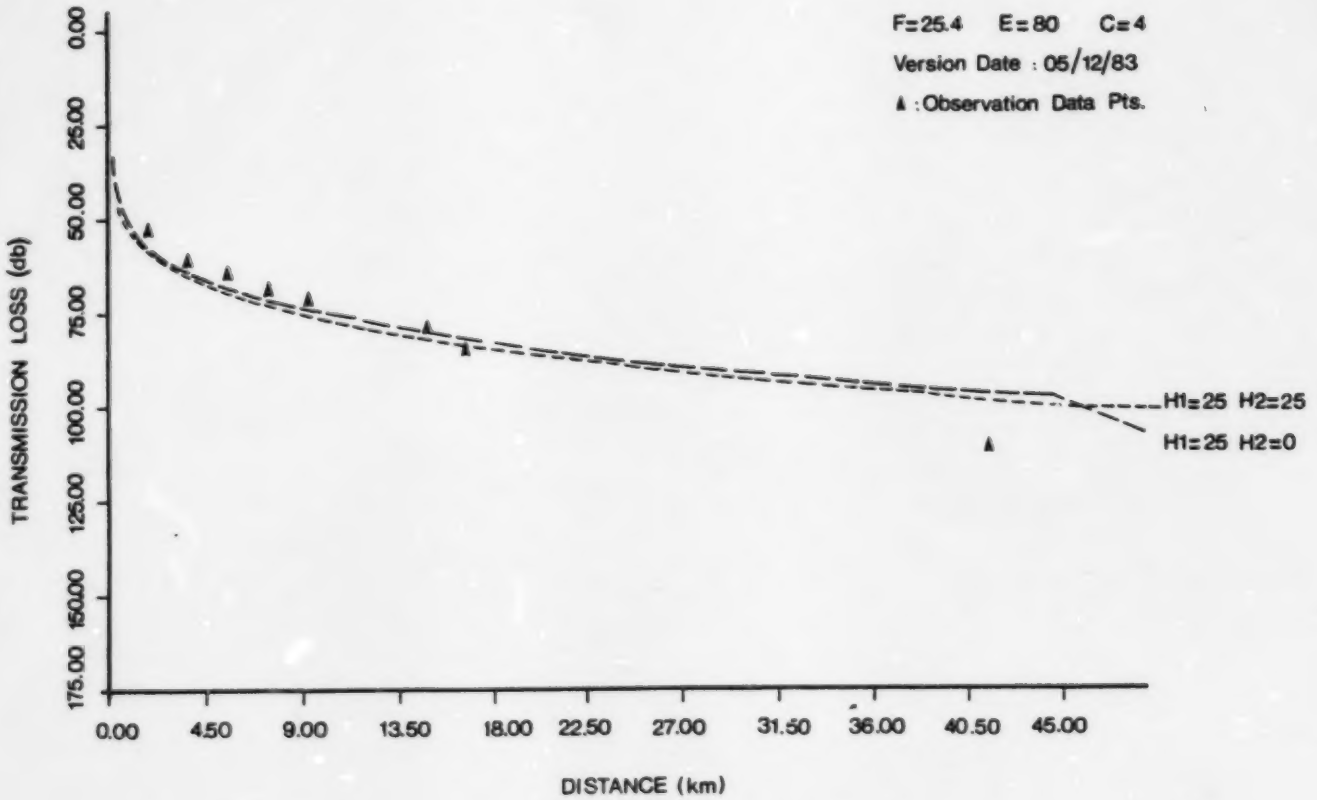


Figure 2 Calculated Transmission Loss Over Sea Water (Flat Earth) versus Transmission Loss Measurements (C-CORE, Strait of Belle Isle, 1983). Wind velocity 25-30 knots, 232-242 degrees with respect to direction of propagation. Frequency = 25.4 MHz, ε_r = 80, σ = 4 mhos/m. H1 = receive antenna height, 25m all measurements. H2 = transmit antenna height, 0m for measurements within 18 km, 25m for measurement at approximately 41 km.

therefore affect the transmission loss calculated.

Barrick (1971) points out that effective surface impedance calculated using a Philips spectrum is a compromise lying between the two values that would result from a Neuman-Pierson spectrum in the case of wind blowing parallel to the radar look angle versus perpendicular to the radar look angle.

Calculated transmission loss based on the flat earth model along with observed transmission loss measurements made by C-CORE are shown in Figure 2. Two transmission loss curves are indicated because two different transmitter antenna heights were used. Loss measurements were made at 25.4 MHz during wind conditions that ranged from 25-30 knots at 232 to 242 degrees with respect to the direction of transmission (propagation).

Table 2 summarizes the loss calculated with the flat earth model (smooth sea) and the observed loss (reflecting sea state. ie. roughness).

Barrick's (1971) graph of "Added Transmission Loss due to sea state at 20 MHz", (the closest frequency to the CODAR frequencies of 25 to 26 MHz) predicts a 2 dB added loss at 10 km. increasing in an approximately linear manner to 9 dB at 40 km. for a 30 knot (56 km/hr) wind. Barrick's calculations use a Philips spectrum to describe sea surface.

Barrick's (1970) graph of "added transmission loss due to sea state at 30 MHz" (predicting 30 knot wind) predicts an almost constant 10 to 11 dB added loss between 10 and 40 km. Note that the "Apparent Added Loss". calculated using the Flat earth model and Barrick's predicted added loss are in general agreement

TABLE 2

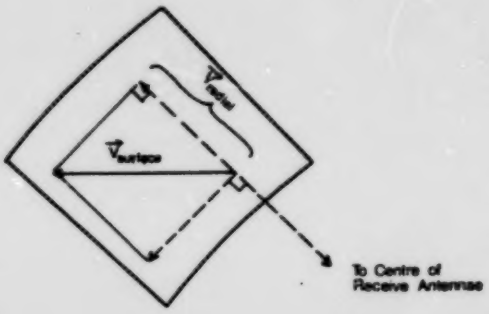
APPARENT ADDED LOSS DUE TO SEA STATE vs. RANGE

Range (km)	Calculated Loss (dB)	Observed Loss (dB)	Apparent Added Loss due to Sea State (dB)
1.85 + 0.2	56.7	52.9 + 3	-3.8
3.71 ± 0.2	64.3	61.9 + 3	-2.4
5.56 + 0.2	68.5	64.7 + 3	-3.8
7.41 + 0.2	71.6	68.8 + 3	-2.8
9.27 + 0.2	74.2	71.6 + 3	-2.6
14.8 + 0.2	80.2	79.1 + 3.5	-1.1
16.7 + 0.2	81.8	84.5 + 3	+2.7
41.5 ± 0.5	98.8	110.9 + 3.5	+12.1

within the accuracy of measurement. The general trend of the observed loss to be slightly less than expected within 15 km and greater past 15 km. is of interest. This is characteristic of "enhancement" but is supposed to occur at lower HF frequencies (Barrick, 1971) and therefore the enhancement question remains open.

As far as a general comparison is concerned it seems reasonable that the effect of roughness accounts for the difference between loss calculated by flat earth model and observed loss, thus validating the usefulness of the model.

It is important to note that the model is to be used to indicate the change in transmission loss as the salinity of the medium changes; the effect of sea state (roughness) will be dealt with separately.



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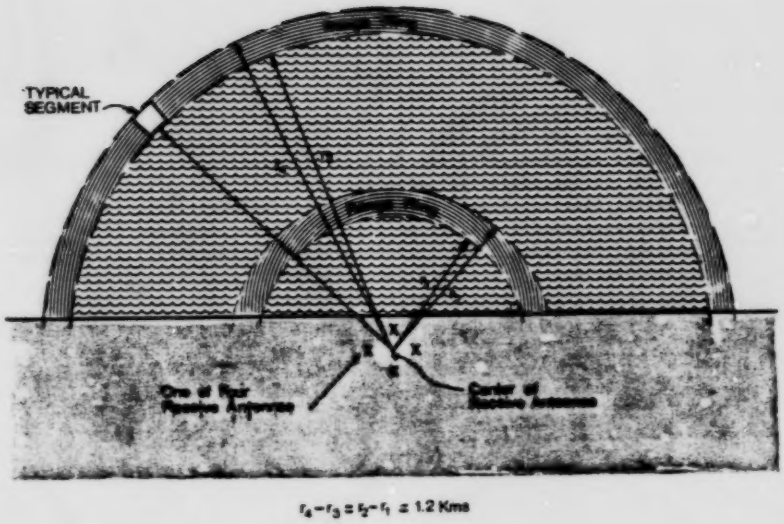

$r_4 - r_3 = r_2 - r_1 \approx 1.2$ Kms

Figure 3 Radial Geometry of the CODAR System.

The Ocean is illuminated with a short pulse of HF energy transmitted from a separate antenna (not shown).

Following transmission, one of the receive antennas is successively sampled at 8μ sec intervals until a total time of 512μsec has elapsed. The process is then repeated with a different receive antenna. Each sample is a measure of the ocean backscatter from a particular range whose range is determined by interval time between time of transmission and time of sampling. Transmission pulse width determines the width of the range ring, 1.2 km.

Each segment of a range ring introduces its own unique (hopefully) Doppler shift into the backscatter; based on the radial velocity component (V_{radial}) of 6 metre ocean waves in that segment. (The radial velocity is the component of the 6 metre ocean wave volocity ($V_{surface}$) in the direction of the receive antenna).

Having separated receive antennas with fixed spacing permits the composite backscatter signal, representing the radial velocities from all segments on a range ring, to be decomposed and radial velocity are assigned to each segment. The result is a radial velocity map on the ocean's surface with respect to the centre of the receiving antennas.

5.0 DEFINITION OF PPERFORMANCE OF CODAR: INCORPORATING EFFECT OF SURFACE ROUGHNESS

This section begins with a simplified description of the form of the data collected by CODAR and how that data is used to produce surface current maps. The criteria used in the data processing to produce surface current maps will also be used to evaluate CODAR's performance. The question then is what is the maximum range to which surface currents can be mapped.

5.1 CODAR: Simplified Description (Refer to Figure 3)

The description that follows is for the benefit of readers who are unfamiliar with CODAR. It is as non-technical as is practical and may be over simplified. A more technical description may be found in the text and references of Butt and Jeans, 1981.

After illuminating the ocean with a 8 or 16 μ sec electromagnetic pulse in the HF band, CODAR collects some of the backscattered signal with four identical but separate antennas.

Time of arrival and transmit pulse width determine the apparent distance to the area where the backscatter occurred, and the resolution in range respectively. At the present time the resolution is 1.2 km in range for the 8 μ sec pulse. Therefore for each time of arrival there is a corresponding inner and outer circle with a radius difference of 1.2 km whose centres are located at the centre of the receive antenna system. This 1.2 km wide annulus, from which the backscatter is deemed to originate at a particular time, is commonly referred to as a "range ring"

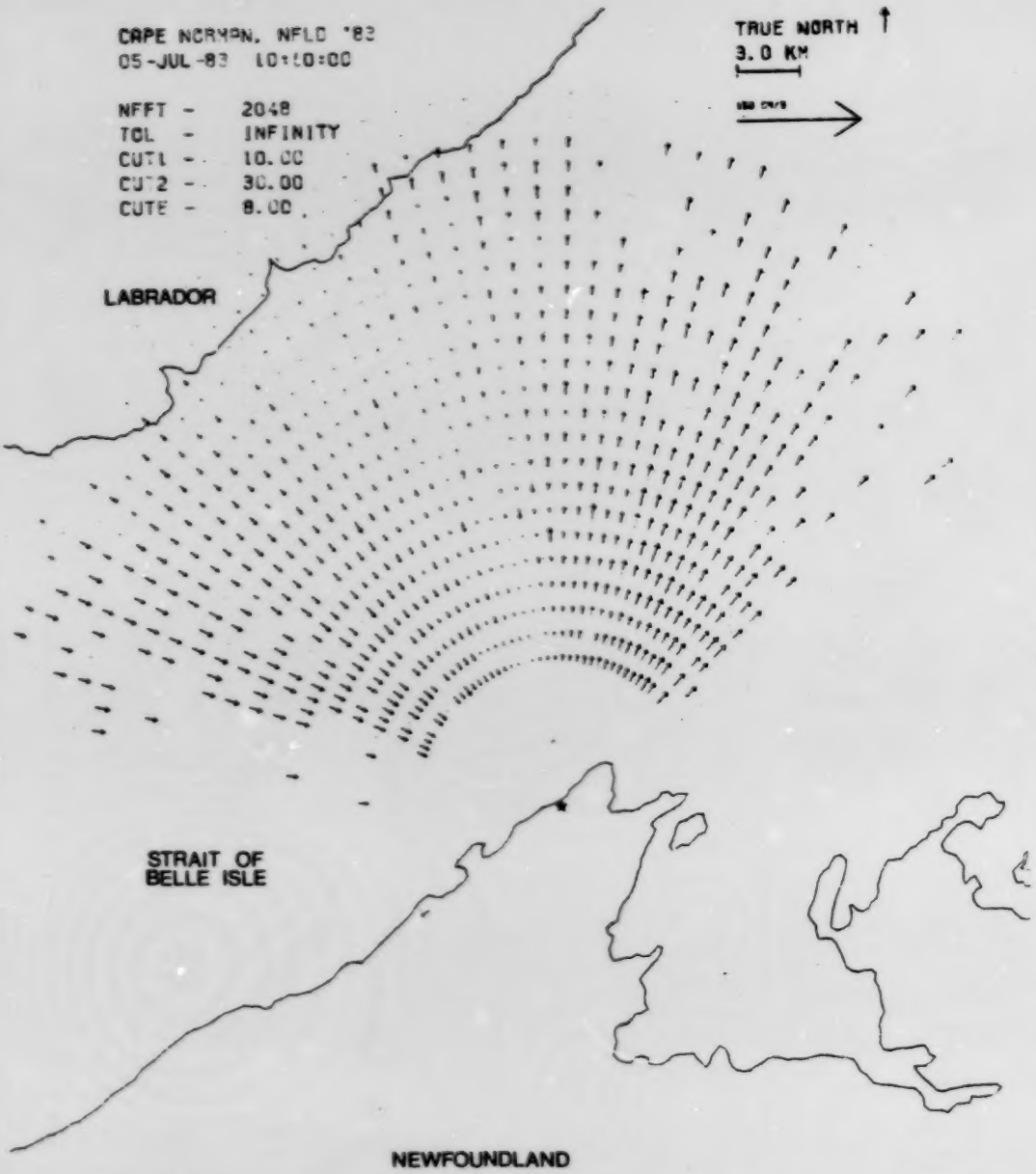

Figure 4 Radial surface current map, recently made with CODAR. The "star" indicates the location of the radar. Length of arrows indicates magnitude of radial component of velocity.

or "range cell". Longer times of arrival correspond to more distant range rings.

CODAR collects the backscatter signal from a maximum of 64 range rings. The first ring lies between 0 and 1.2 km in range, although practically the first useable range ring lies beyond 6 km.

The data collection process continues until a time history of the signal at each receive antenna for each range ring has been obtained.

Each time series (time history) for each antenna at each range cell is then Fourier transformed into the frequency domain. Therefore for a particular range ring there exists one Fourier transform of the received signal for each of the four antennas. The relative spacing between antennas allows a particular frequency component present in all four spectra (transforms) to be located in azimuth. Each frequency component is unique and corresponds to a particular radial component of the surface current velocity (originating from a specific segment within the range ring) ie. only the component of the surface current moving towards or away from the radar is measured. The result is a map of the radial components of the surface current on the ocean relative to the centre of the four receive antennas. See Figure 4.

5.2 Fourier Transform

The Fourier transforms actually contain a mixture of information, on sea state and noise, in addition to radial

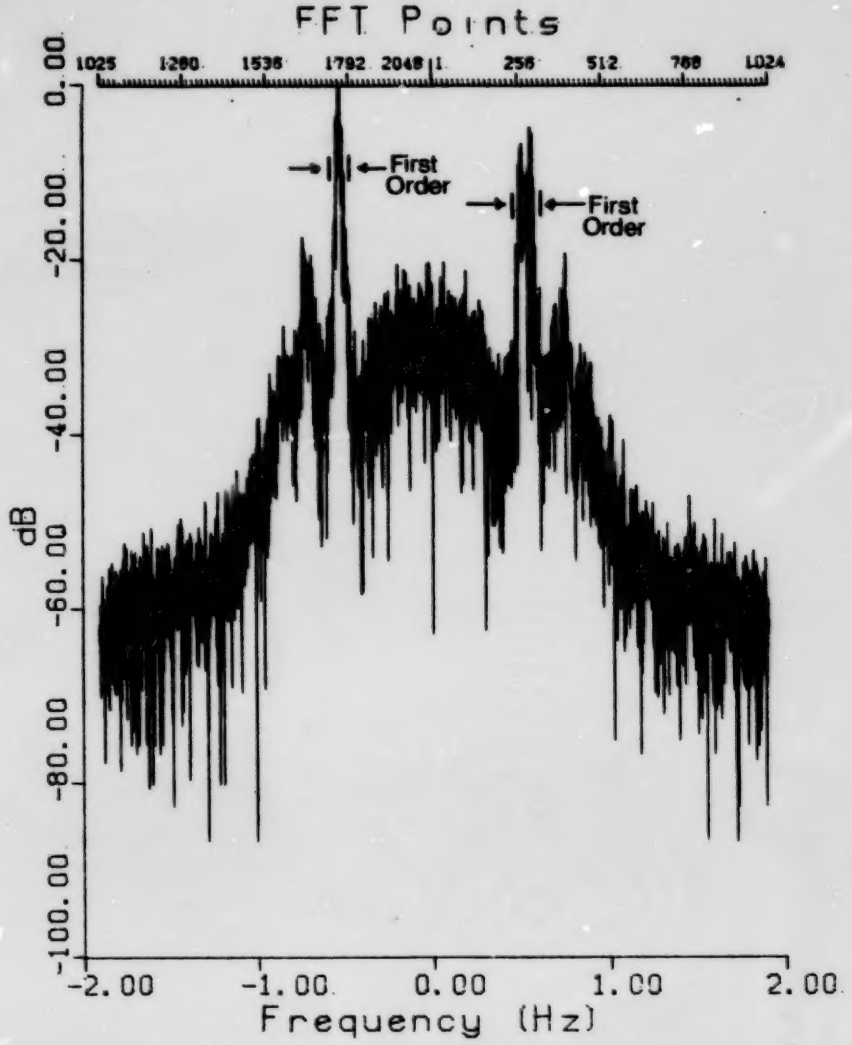

Figure 5 Relative Power Doppler Spectrum of ocean at 25.4 MHz recently recorded with CODAR.

*The processing system, at present, ignores the first 4 range cells, designating the fifth range cell, "range cell 1". The actual range cell is 9, corresponding to a range annulus between 9.6 and 10.8 km.

current velocities. The performance of CODAR is limited by the ability of the data processing to delineate the signals representing radial current velocities from all other signals in the Doppler spectrum (Fourier transform).

The problem is analogous to defining the minimum signal to noise ratio acceptable for an electrical measurement.

It is appropriate to start with a general description of the typical Doppler spectrum representing the frequency content of the backscattered signal from a range ring. (Refer to Figure 5). "Frequency" refers to Doppler shift, zero Doppler corresponding to no shift in the backscatter characteristic of fixed targets (eg. land). A positive shift (frequency greater than zero) is characteristic of backscatter from a target moving towards the radar while a negative shift frequency less than zero) is characteristic of backscatter from a target moving away from the radar.

The characteristic Doppler spectrum at HF including the scattering mechanism, is very well described by Barrick et al., (1974).

A few of the salient points follow. At the frequency of interest (25.4 MHz) first order scattering will occur from 6 metre ocean waves travelling towards. (positive Doppler shift), and away from, (negative Doppler shift), the radar, as indicated in Figure 5. These parts of the Doppler spectrum contain the radial surface current information. The two indicated peaks cluster about two intrisic Dopplers ± 0.514 Hz, determined by the natural phase velocity of 6 m waves and the frequency of interest

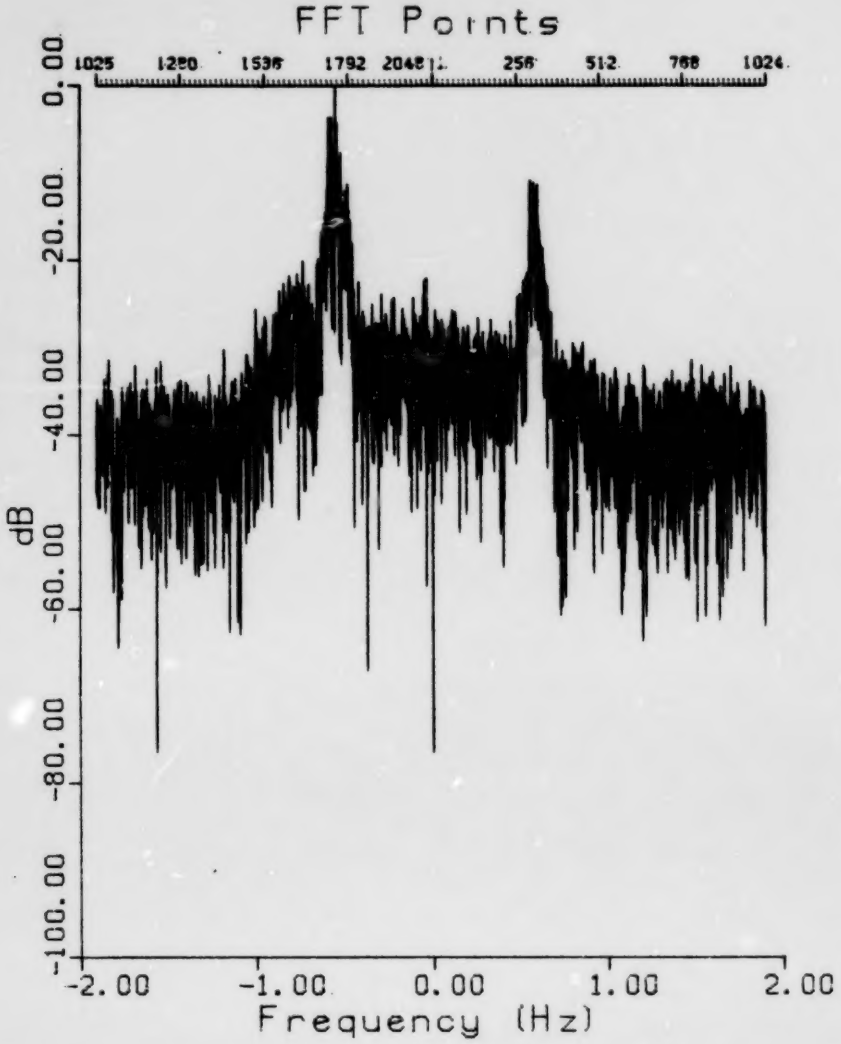

Figure 6 **Relative Power Doppler Spectrum of ocean at 25.4 MHz recently recorded with CODAR.**

***The processing system at present ignores the first 4 range cells disignating the fifth range cell, "range cell 1". The actual range cell is 21, corresponding to a range annulus between 24 and 25.2 km.**

25.4 MHz. The shift of the first order from ±0.514 Hz can be related to the radial surface currents.

For the purposes of mapping surface currents, the rest of the spectrum outside the first order regions is not useful and will be treated as noise although this region is actually composed of a combination of sea state information, atmospheric noise, and system noise.

The shape of the spectrum is variable depending on range, wind, and sea conditions; compare Figure 5 with Figure 6.

5.3 Maximum Range

The question posed at the beginning of this section now changes. Allowing for wind and sea conditions, what is the maximum range at which the first order region still is sufficiently strong to be separated from the surrounding spectrum?"

Doppler spectrums from a CODAR data set collected in the summer of 1983 from the Strait of Belle Isle were used to calculate the effective surface current mapping range. The first order region was considered acceptable, if after being identified, at least one of the two regions of first order contained on average 6 dB more power per individual Doppler than the surrounding area just outside the designated region. The farthest range cell satisfying this condition determined the maximum range of the system. An example of this process is shown in Figure 7 where the right hand side first order region was calculated to contain an average 9.26 dB more power per Doppler

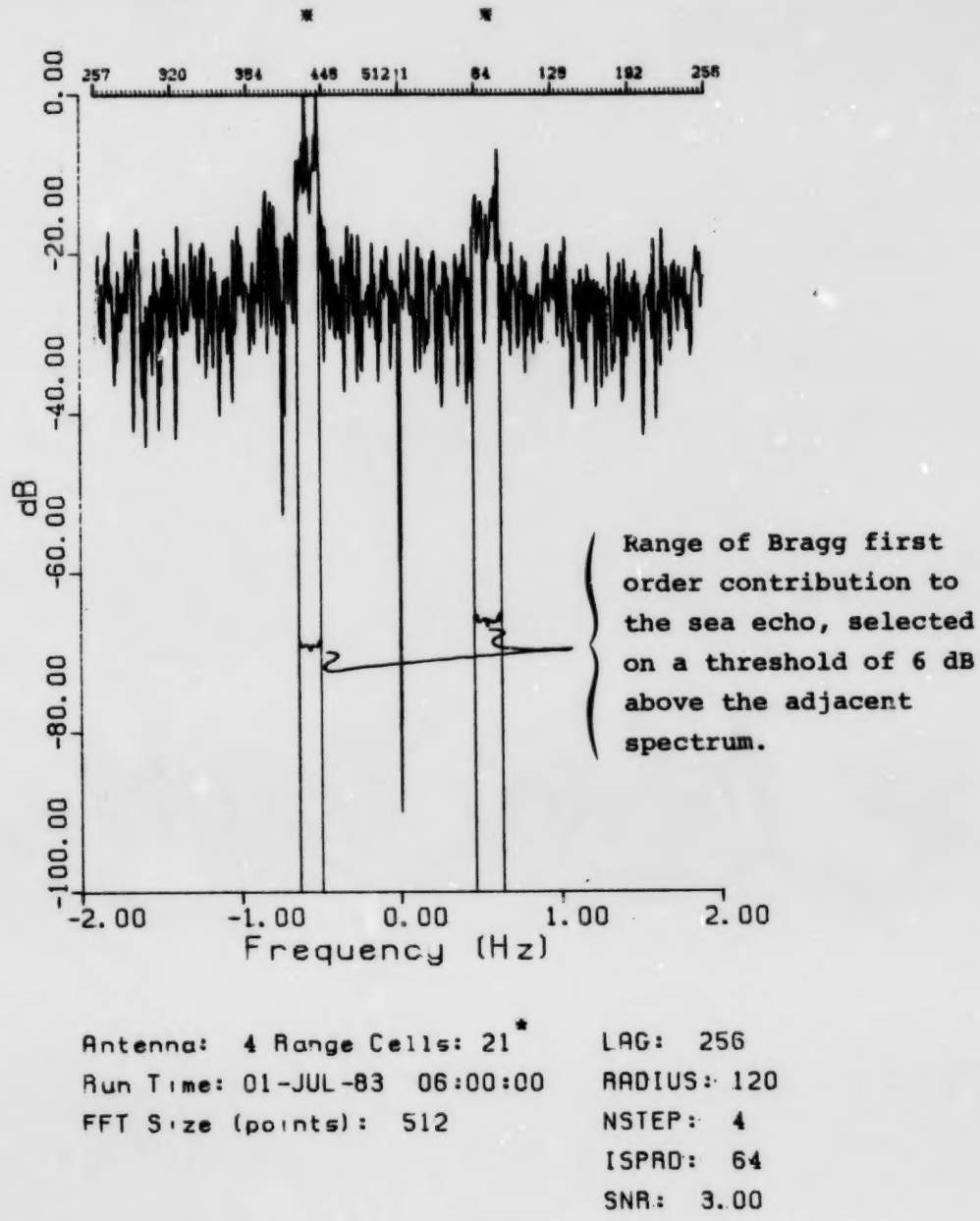

Figure 7 Relative Power Doppler Spectrum of ocean at 25.4 MHz recently recorded with CODAR.

*The processing system at present ignores the first 4 range cells, disignating the fifth range, "range cell 1". The actual range cell is 25, corresponding to a range annulus between 28.8 and 30.0 km.

frequency than its adjacent surrounding spectrum. Similarly a value of 14.76 dB was calculated for the left hand side.

TABLE 3

MAXIMUM RANGE vs. WIND SPEED

WIND SPEED	NO. OF SAMPLES	MAXIMUM RANGE
Calm	4	36.9 ± 3.0 km
0^+ to 5 knots	5	37.4 ± 3.1 km
5^+ to 10 knots	7	35.0 ± 2.8 km
10^+ to 15 knots	6	36.4 ± 2.8 km
15^+ to 20 knots	3	38.4 ± 2.4 km
Calm to 20 knots	25	36.5 ± 2.9 km

The results are listed in Table 3. Unfortunately an absence of wind during surface current measurements does not immediately result in a smooth ocean. Hence, the lack of correlation between wind speed and maximum range.

It is observed that the effective range of CODAR as previously defined averaged out to 36.5 km ± 2.9 km during a variety of wind conditions. It is worth pointing out that the samples were initially selected in the expectation of relating wind speed to range, and are not representative of typical wind conditions. From 80 measurements of wind velocity during the 10

days enveloping the data collection period, the average wind speed is calculated to be 13.7 knots ± 7.5 knots. Consequently the ocean surface had little opportunity to settle down.

Therefore this figure reflects the effect of ocean roughness on CODAR's performance and is the best estimate available to use with the flat earth model to predict maximum range over waters of lower salinities.

6.0 ELECTRICAL PROPERTIES; SEA WATER, BRACKISH WATER

In this section, literature describing the relationship between electrial properties of saline water and salinity will be discussed. Useful formulas will be applied to determine electrical properties for water ranging from fresh to very saline (sea water).

Since electrical properties usually vary with frequency it should be remembered that the area of interest is in the HF band.

6.1 Complex Permittivity

A medium may be described electrically by its complex permittivity, (ε_*), which is designated in the literature as n_o^2,

$$\text{where;} \quad \varepsilon_* = n_o^2 = \varepsilon' - j\varepsilon = \varepsilon_r - \frac{j\sigma_o}{\omega\varepsilon_o} \tag{25}$$

ε_r = the relative permittivity of the medium

ε_o = the permittivity of free space

σ_o = the conductivity of medium

The quantity n_o^2 has also been called the refractive index by analogy to optical theory. The quantities ε_r and σ_o are, in general. frequency dependant but usually assumed constant.

6.2 Relation ε_r, σ to Salinity

Saxton and Lane, 1952,develop equations to calculate ε_r, σ for any sodium chloride solution at any frequency and temperature. They also point out that the dielectric properties

of sea water will be closely approximated by those of a 0.62 Normal (36°/oo) solution of NaCl in water.

The formulas given in that paper are.

$$\varepsilon' = \frac{\varepsilon_s - \varepsilon_\rho}{1 + \chi^2} + \varepsilon_\rho \qquad (26)$$

pure water

$$\varepsilon'' = \frac{\varepsilon_s - \varepsilon_\rho}{1 + \chi^2} \qquad (27)$$

where

$\chi = \omega\tau$

τ = relaxation time

ε_ρ = dielectric constant, representing electronic and atomic polarization

ε_s = static dielectric constant

Taking into account dissolved solute, such as NaCl, in water. Saxton and Lane add a term to the equation for ε'' to account for ionic conductivity resulting in,

Water solution

$$\varepsilon'' = \frac{(\varepsilon_s - \varepsilon_\rho)}{1 - \chi^2} + 2\frac{\sigma_i}{f} \qquad (28)$$

where σ_i is the ionic conductivity in e.s.u. and f the frequency of interest, and the equation for ε' remains unaffected.

The above equations can also be found in Hasted, Ritson, and Collie (1948) Saxton and Lane (1952) use a value of 4.9 for ε_ρ for NaCl solutions, and list values of ε_s, τ, and σ_i for 0, 0.5, 1.0N (normal) solutions of NaCl at 0, 10, and 20°C.

In order to calculate ε_r and σ for **any** salinity it will be necessary to fit a straight line to the data points for ε_s, τ, and σ_i. This effectively infers that ε_s, τ and σ_i are linear functions of the normality of solution. However only ε_s and τ truly exhibit linearity with changing normality (Lane and Saxton, (1952)).

Therefore we are introducing some measure of error in our estimate of σ_i. Calculated correlation coefficients, however, show that the amount of error is not excessive.

Denoting the normality of the NaCl solution to be N, linear regression yields;

i) $\tau = m_\tau N + b_\tau$ (29)

Temperature	m_τ	b_τ	correlation coefficient
0°C	-2.3×10^{-12} sec	1.855×10^{-11} sec/N	-0.975
10°C	-1.8×10^{-12} sec	1.343×10^{-11} sec/N	-0.952
20°C	-1.1×10^{-12} sec	9.98×10^{-12} sec/N	-0.939

ii) $\varepsilon_s = mN + b$ (30)

Temperature	m	b	correlation coefficient
0°C	-19	87.5	-0.996
10°C	-18	83.67	-0.998
20°C	-17	79.83	-0.999

iii) $\sigma_i = m_{\sigma_i} N$ (σ_i must be zero for N = 0) (31)

Temperature	m_{σ_i}	correlation coefficient
0°C	4.32×10^{10} e.s.u./N	0.999
10°C	5.72×10^{10} e.s.u./N	0.991
20°C	7.12×10^{10} e.s.u./N	0.981

Comparison of equations 26 and 28 with 25 yield,

$$\sigma(\text{mhos/m}) = \frac{f}{18\times10^9} \frac{(\varepsilon_s - \varepsilon_\rho)\omega\tau}{(1 + \omega^2\tau^2)} + \frac{\sigma_i(\text{e.s.u.})}{9\times10^9 \frac{\text{e.s.u.}}{\text{mhos/m}}} \quad (32)$$

$$\varepsilon_r = \frac{(\varepsilon_s - \varepsilon_\rho)}{(1 + \omega^2\tau^2)} + \varepsilon_\rho \quad (33)$$

Where a conversion from e.s.u. to mhos/m has been made for σ.

Finally. since 0.62N NaCl solution corresponds to 36°/oo.

$$\text{Salinity } (^{o}/oo) = \frac{36^{o}/oo}{0.62N} \times \text{Normality}$$

$$= 58.06 \times \frac{\text{Normality } ^{o}/oo}{N} \qquad (34)$$

Equations 29 through 34 were used to calculate ϵ_r and σ. for the particular frequency of CODAR. f = 25.4 MHz. for a variety of salinities. The results are listed in Table 4.

TABLE 4: Calculated ϵ_r. σ vs Salinity and Temperature

TEMP	SAL. PPT	REL. PERM	COND. MHO/M	TEMP	SAL. PPT	REL. PERM	COND. MHO/M	TEMP	SAL. PPT	REL. PERM	COND. MHO/M
0.	0	87.499	0.000345								
0.	1	87.172	0.083009	10.	0	83.670	0.000238	20.	0	79.830	0.000168
0.	2	86.845	0.165472	10.	1	83.360	0.109692	20.	1	79.537	0.138413
0.	3	86.518	0.248336	10.	2	83.050	0.219146	20.	2	79.244	0.272657
0.	4	86.190	0.330999	10.	3	82.740	0.328600	20.	3	78.951	0.408901
0.	5	85.863	0.413663	10.	4	82.430	0.438054	20.	4	78.659	0.545145
0.	6	85.536	0.496326	10.	5	82.120	0.547508	20.	5	78.366	0.681389
0.	7	85.209	0.578990	10.	6	81.810	0.656962	20.	6	78.073	0.817634
0.	8	84.882	0.661653	10.	7	81.500	0.766416	20.	7	77.780	0.953878
0.	9	84.554	0.744317	10.	8	81.190	0.875870	20.	8	77.488	1.090122
0.	10	84.227	0.826980	10.	9	80.880	0.985323	20.	9	77.195	1.226366
0.	11	83.900	0.909644	10.	10	80.570	1.094777	20.	10	76.902	1.362610
0.	12	83.573	0.992307	10.	11	80.260	1.204231	20.	11	76.609	1.498854
0.	13	83.246	1.074971	10.	12	79.950	1.313685	20.	12	76.317	1.635099
0.	14	82.918	1.157634	10.	13	79.640	1.423139	20.	13	76.024	1.771343
0.	15	82.591	1.240298	10.	14	79.330	1.532593	20.	14	75.731	1.907587
0.	16	82.264	1.322962	10.	15	79.020	1.642047	20.	15	75.438	2.043831
0.	17	81.937	1.405625	10.	16	78.710	1.751501	20.	16	75.145	2.180075
0.	18	81.609	1.488289	10.	17	78.400	1.860955	20.	17	74.853	2.316320
0.	19	81.282	1.570952	10.	18	78.090	1.970409	20.	18	74.560	2.452564
0.	20	80.955	1.653616	10.	19	77.780	2.079863	20.	19	74.267	2.588808
0.	21	80.628	1.736280	10.	20	77.470	2.189317	20.	20	73.974	2.725052
0.	22	80.301	1.818943	10.	21	77.160	2.298771	20.	21	73.682	2.861296
0.	23	79.973	1.901607	10.	22	76.850	2.408225	20.	22	73.389	2.997541
0.	24	79.646	1.984271	10.	23	76.540	2.517679	20.	23	73.096	3.133785
0.	25	79.319	2.066934	10.	24	76.230	2.627133	20.	24	72.803	3.270029
0.	26	78.992	2.149598	10.	25	75.920	2.736587	20.	25	72.510	3.406273
0.	27	78.665	2.232261	10.	26	75.610	2.846041	20.	26	72.218	3.542517
0.	28	78.337	2.314925	10.	27	75.300	2.955495	20.	27	71.925	3.678762
0.	29	78.010	2.397589	10.	28	74.990	3.064949	20.	28	71.632	3.815006
0.	30	77.683	2.480253	10.	29	74.680	3.174403	20.	29	71.339	3.951250
0.	31	77.356	2.562916	10.	30	74.370	3.283857	20.	30	71.047	4.087495
0.	32	77.028	2.645580	10.	31	74.060	3.393311	20.	31	70.754	4.223739
0.	33	76.701	2.728243	10.	32	73.750	3.502765	20.	32	70.461	4.359983
0.	34	76.374	2.810907	10.	33	73.440	3.612219	20.	33	70.168	4.496227
0.	35	76.047	2.893571	10.	34	73.130	3.721673	20.	34	69.876	4.632472
0.	36	75.720	2.976235	10.	35	72.820	3.831127	20.	35	69.583	4.768716
				10.	36	72.510	3.940581	20.	36	69.290	4.904961

7.0 PREDICTED CODAR RANGE OVER BRACKISH WATER

The effective maximum CODAR range (arrived at in section 5) which incorporates the effect of surface roughness will be translated into maximum tolerable transmission loss. This will be accomplished by making use of the model for transmission loss (section 3) and the electrical properties of sea water (section 6).

Finally, the maximum tolerable transmission loss will determine the effective range of CODAR over brackish water through the use of the flat earth model with the appropriate electrical properties for brackish water (section 6).

7.1 CODAR Range Over Brackish Water: Maximum Tolerable Transmission Loss

The best estimate of CODAR range over sea water incorporating surface roughness (see section 5.3) was found to be 36.5 km ± 2.9 km.

Using the flat earth model (section 3) and the relationships between salinity, temperature and relative permittivity, conductivity, (section 6), one way transmission loss was graphed for different brackishness and temperature. See Figures 8, 9 and 10 (pp. 40-42).

Since the CODAR maximum range was calculated based on data collected over sea water near 0°C the loss curve in Figure 8 corresponding to 36 (3.6%) and 0°C will be used to translate maximum range into maximum tolerable transmission loss.

First it must be pointed out that the loss curves are for one way path loss. CODAR is subject to two way path loss since loss is incurred both in broadcasting to a particular range and then for the backscatter returning over the same path to the receiving antennas.

Therefore the true loss associated with range is actually twice the one way path loss when working in dB.

The numerical equivalents of Figures 8, 9 and 10 are contained in Appendix B.

Using the tabulated values for the previously mentioned curve yeilds,

Table 5

ONE WAY, TWO WAY TOLERABLE TRANSMISSION LOSS VERSUS RANGE

Range	One Way Tolerable Transmission Loss	Two Way Tolerable Transmission Loss
36.5 - 2.9 = 34.6 km	94.94 dB	189.88 dB
36.5 kms	96.60 dB	193.20 dB
36.5 + 2.9 = 39.4 km	98.17 dB	196.34 dB

Therefore the maximum tolerable loss determining CODAR's maximum range can be described as:

from 94.94 dB to 98.17 dB, (one way path loss)

or, from 189.88 dB to 196.34 dB (two way path loss).

For a particular one way loss curve, the maximum range of CODAR will lie between the range at which the curve indicates 94.94 dB and the range corresponding to 98.17 dB. However, there are limitations to this statement.

First, the "maximum tolerable loss" included the effect of roughness over a distance of approximately 36 km; the roughness contribution to loss will decrease with decreasing range (see Barrick 1971). Therefore when a much smaller range than 36 km is indicated, bear in mind that the additional loss due to roughness has probably been over-estimated and the range prediction will be pessimistic.

Secondly the propagation theory used assumes the medium is a good conductor. This assumption starts to break down as the water becomes less saline.

Thirdly, the range predictions reflect the current capability of C-CORE's CODAR system as of 1983. Improvements in processing as well as in hardware should extend the range of CODAR. Finally variations in atmospheric noise have not been addressed. An increase in atmospheric noise due to location would depress the performance of CODAR.

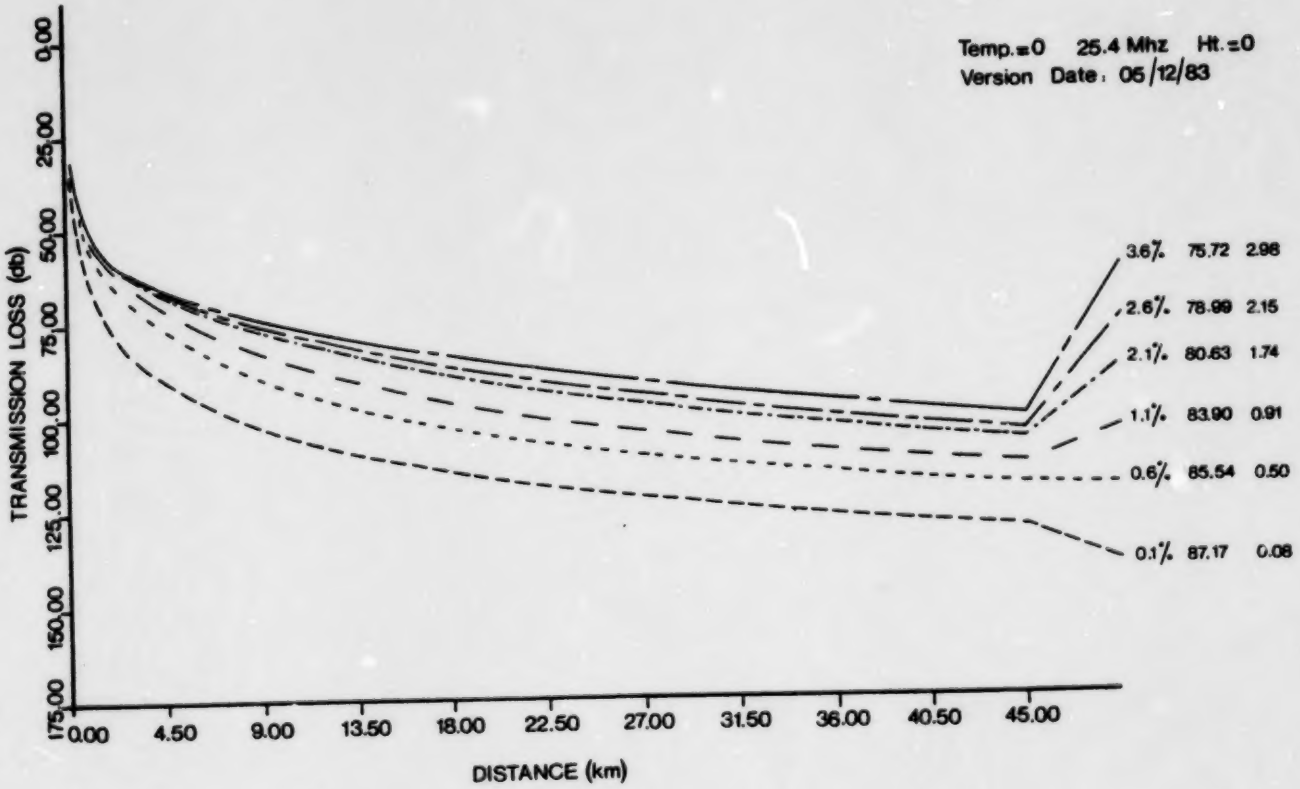

Figure 8 One way transmission loss over brackish water. Frequency of interest 25.4 MHz. Antenna height = 0. Temperature = $0^{o}C$. The three numbers trailing each curve are; salinity in precent, relative permittivity, conductivity in mhos/m.

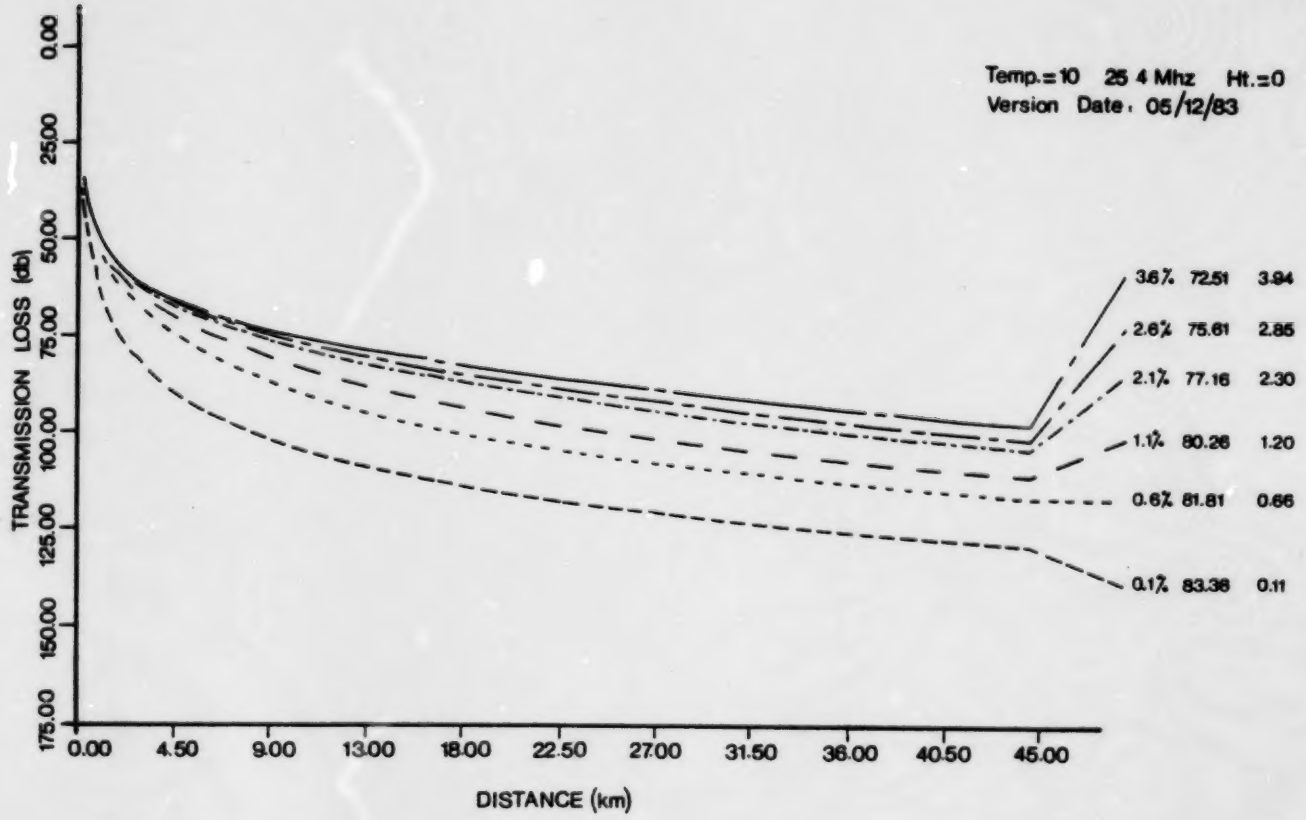

Figure 9 One way transmission loss over brackish water. Frequency of interest 25.4 MHz. Antenna height = 0. Temperature = 10°C. The three numbers trailing each curve are; salinity in percent, relative permittivity, conductivity in mhos/m.

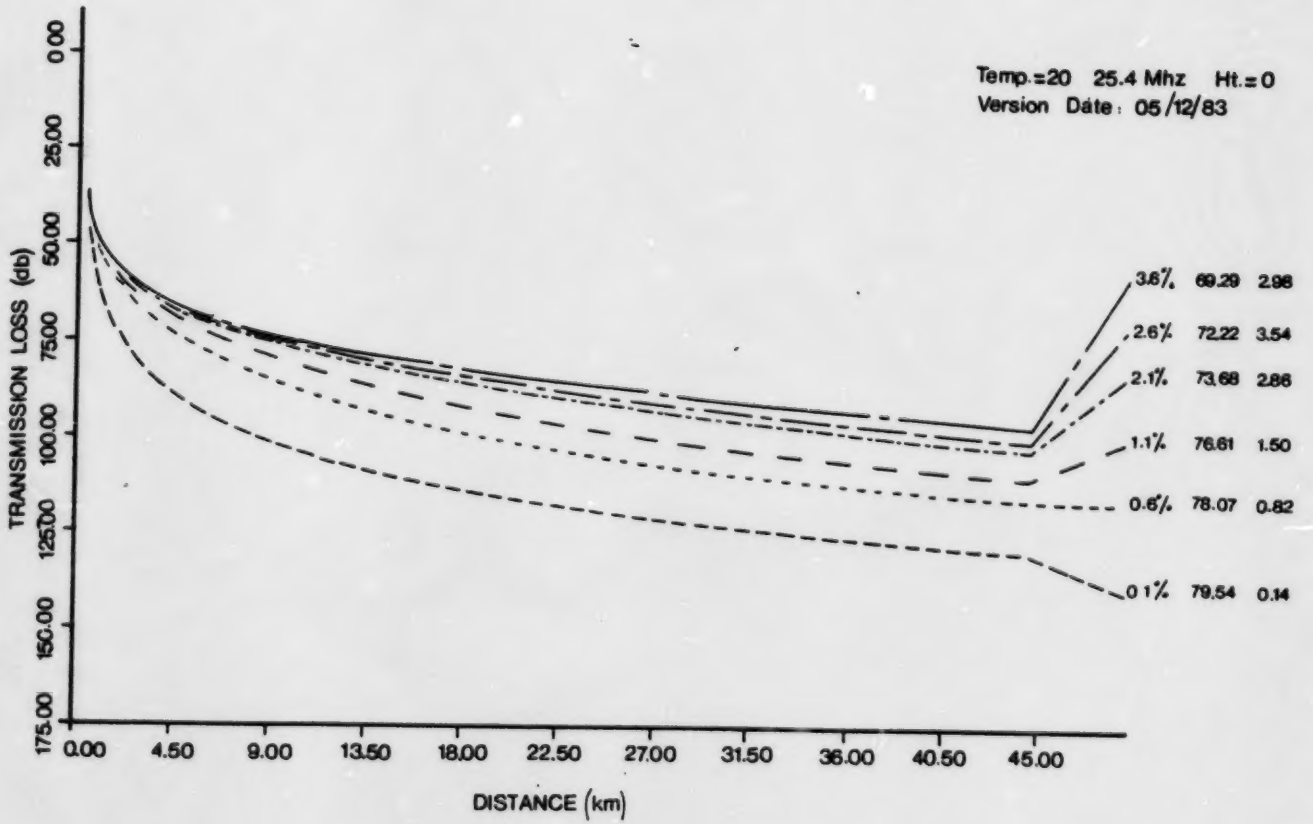

Figure 10 One way transmission loss over brackish water. Frequency of interest 25.4 MHz. Antenna height = 0. Temperature = 20°C. The three numbers trailing each curve are; salinity in percent, relative permittivity, conductivity in mhos/m.

8.0 DETERIATION OF PERFORMANCE OVER SEA ICE

Presence of large amounts of sea ice within CODAR's otherwise normally effective range will probably depress CODAR's performance severely.

8.1 Excessive Transmission Loss Expected

Recent propagation studies by C-CORE (see Klein and Butt, 1983) indicate much more attenuation is to be expected over sea ice than over sea water.

A graph of transmission loss for approximately 1 metre of sea ice above sea water is shown in Figure 11, (Klein and Butt, 1983). Note the curve indicates a loss value of ~ 105 dB at only 1 km!

Attention should be given to expected ice conditions prior to a CODAR survey, and an appropriate time slot identified when ice coverage is negligible.

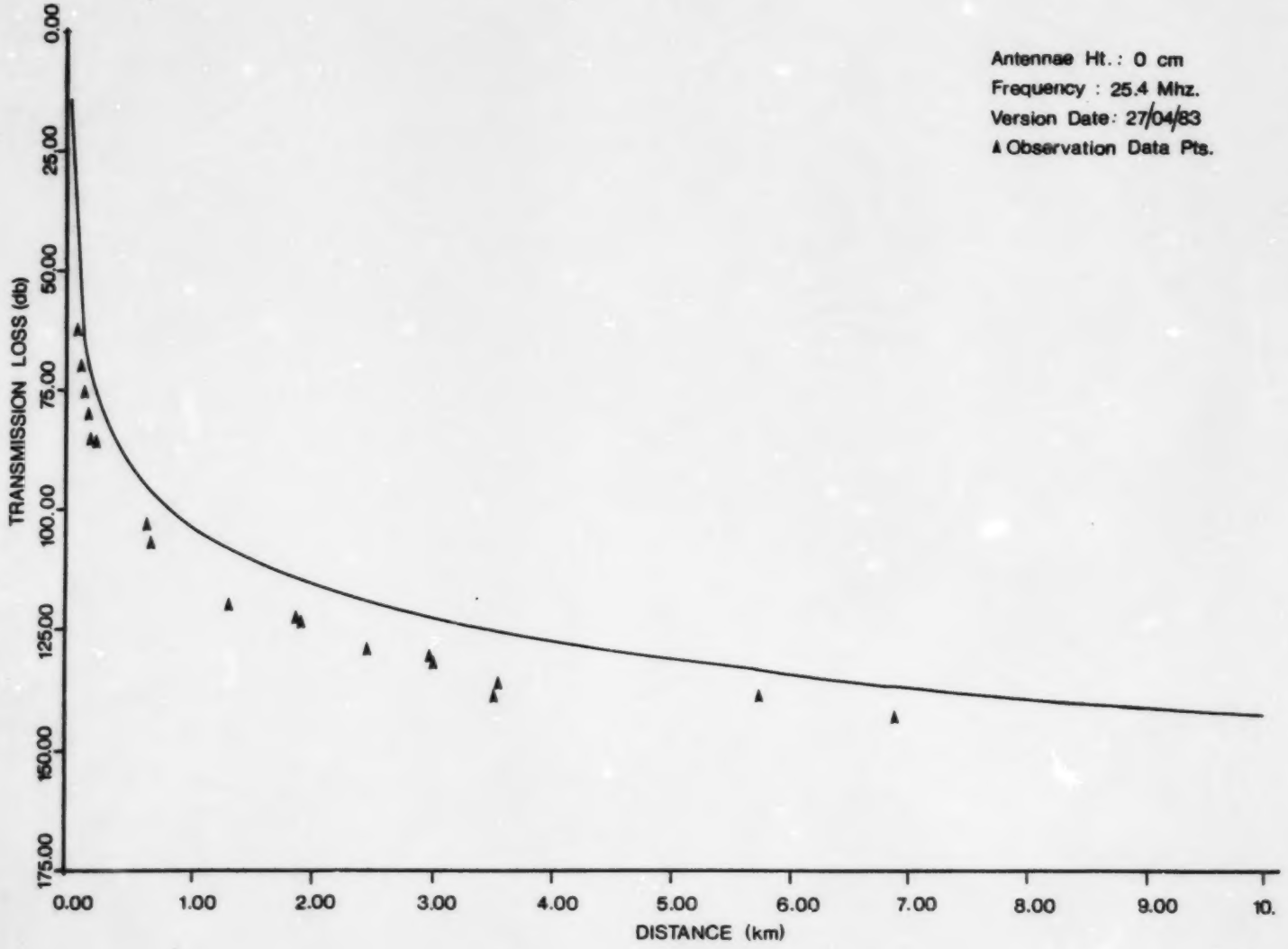

Figure 11 Loss: Observed vs Theoretical (Gt = Gr = 1).
Transmission Loss Over Sea Ice

9.0 DETECTION OF ESTUARINE FRONTS: AN EXAMPLE

In this section an estimate is made of the ability of CODAR to locate the boundary of an estuarine front. Sample calculations will be made characterizing the plume of the Saguenay River in the St. Lawrence. The modelling procedure used requires the salinity structure of the plume and surrounding water to be simplified into two distinct regions, each homogeneous. In reality the plume and surrounding water both have a very complex and variable salinity structure. Therefore the model is a simplistic approximation to a very complex phenomenon.

9.1 Detection of the Boundary

With the present CODAR system two means of identifying an estuarine front boundary merit consideration. If the surface currents of the front are moving at a different velocity (speed or direction) than the surrounding water, it should affect the uniformity of a surface current map measured with CODAR. This could be one method of locating the boundary of an estuarine front. Alternatively, the backscatter from the boundary between the front and surrounding water may be sufficiently strong to be identified in the Fourier transforms described in Section 5. The signal attributed to the boundary could then be decomposed into range and azimuth. This assumes that the backscatter signal appears in each range cell containing part of the boundary so that the **entire** boundary within the field of view of CODAR can be located.

The magnitude of the backscatter must be calculated, to be used to estimate the radar cross-section of the plume.

9.2 Theory

The equations for backscatter and transmission loss are based on the work of Walsh, 1983. The equations used reflect further derivation by Walsh. and these versions are not yet published. S. Srivastava implemented these equations in a computer algorithm applying the calculations for the specific case in question.

Two specific areas were addressed; quantifying the expected backscatter from the plane boundary and estimating transmission loss with the plume present.

9.2.1 Backscatter Model

Calculation of backscatter is made with the following information:

i) frequency of operation,
ii) receive and transmit antenna gains,
iii) complex normalized surface impedance of the plume region,
iv) complex normalized surface impedance of the region surrounding the plume,
v) peak power transmitted.

The following conditions also apply:

i) Both regions are flat and smooth,
ii) Each region is homogeneous and can be represented by one

complex surface impedance,

iii) The antennas are on the surface (ie. no elevation),

iv) The geometry is indicated in Figure 12.

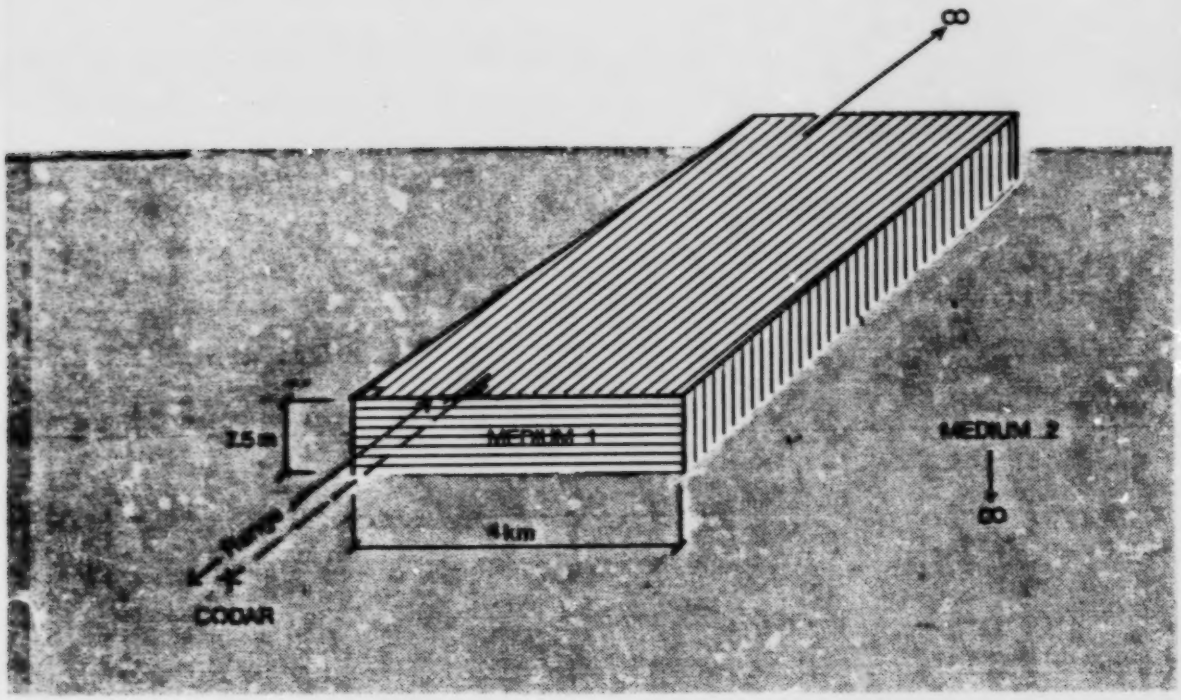

Figure 12 Model of Plume and Surrounding Water at Ebb Tide.

The plume is characterized as rectangular and semi-infinite in length. Extending the line from the radar location to past the centre of the front edge of the plume would bisect the rectangle. The line is perpendicular to the front edge of the plume. The region within the semi-infinite rectangle is characterized by a single surface impedance. The area outside the rectangle is characterized by a different single surface impedance.

A rectangular slab semi-infinite in length (medium (1)) is bounded by a mass (medium (2)) semi-infinite in depth. Each medium is electrically homogeneous. The slab has a thickness of 7 1/2 metres. At ebb tide the slab (representing the plume) has a salinity between 20°/oo (best case for backscatter) and 26°/oo (worst case). The surrounding water has a salinity of 29°/oo. Both mediums are at 4°C. The slab is 4 km wide.

9.2.2 Transmission Loss When the Plume is Present: The Model

In addition to the possibility of backscatter from the plume boundary, the estimated range of CODAR to measure surface currents over a single medium (see section 7) may be modified by the presence of two electrically different regions in the area of interest.

To anticipate this situation it is necessary to look at the magnitude of the equivalent of the Norton Attenuation Function which will be denoted by "G". "G" when substituted for F(w) in equation 14, (Section 2) permits the calculation of one way transmission for the two media situation.

As in the previous section the equations used are based on the work of Walsh, 1983, and the computer algorithm implemented by S. Srivastava.

The geometry is indicated in Figure 13. Calculation of "G" is made with the following information:

i) Frequency of operation,

ii) Infinitesimal dipoles for transmit and receive antennas,

iii) Complex normalized surface impedances for both media,

iv) Distance of transmit antenna to discontinuity (r_o).

The following conditions also apply:

i) Both surfaces, media (1) and (2) one flat and smooth,

ii) The antennas are at the surface (ie. no elevation),

iii) Each medium is homogeneous.

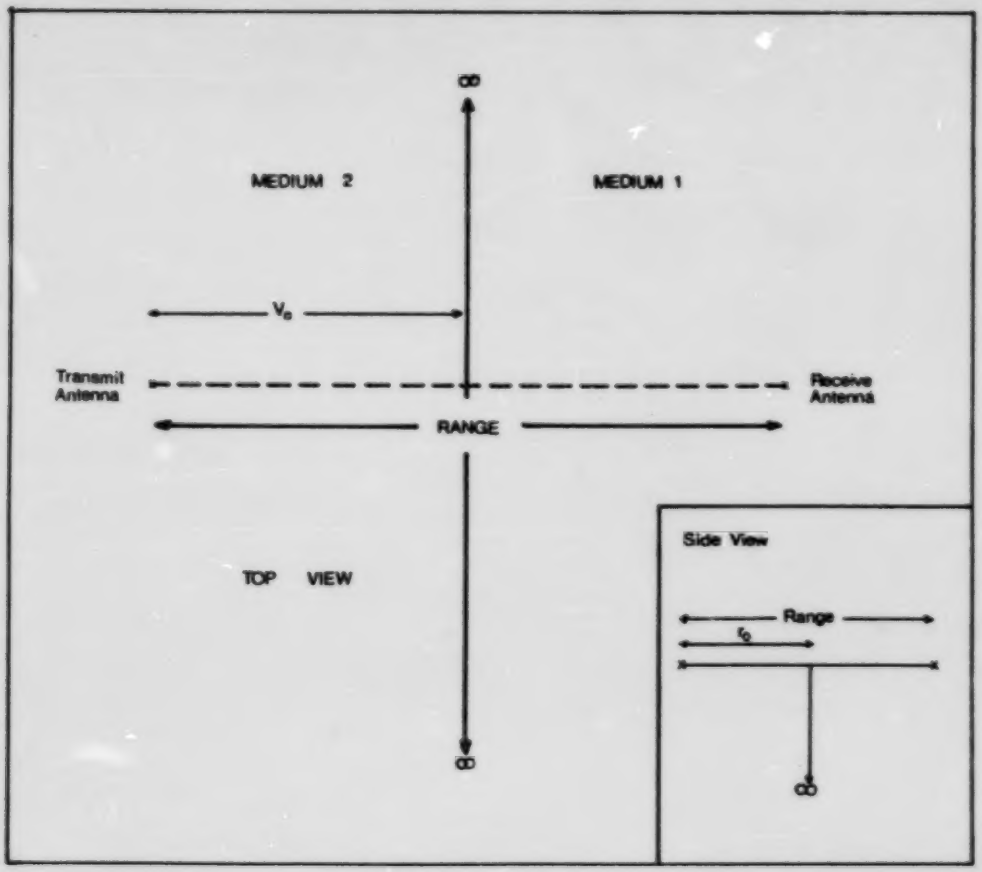

Figure 13 Geometry for evaluation of "G". Two semi-infinite flat media, (1) and (2), each homogeneous but electrically dissimilar form a semi-infinite lower half space. Free space forms the upper semi-infinite half space. The distance from the transmitting antenna to the boundary between media (1) and (2) is r_o. The distance separating the antennas is the range for which G is calculated.

9.3 Modelling the Plume of the Saguenay and the Surrounding St. Lawrence

The salinity, temperature, and geometry of the plume of the Saguenay and the surrounding St. Lawrence are described by Lebel et al., 1983, from measurements made during the month of November, 1979.

Their published graphs of lines of constant salinity and temperature versus depth for the plume region during ebb tide were simplified in order to model the backscatter.

Before the modelled plume is defined attention is drawn to conclusions based on a discussion with one of the authors of the paper.

The month of November was chosen for measurements because of the low volume of fresh water runoff in the area of interest. However the plume's description is probably valid during times of ice free conditions. The plume's boundaries are indicated by a fairly rapid change in salinity across the boundary. Finally Lebel et al., 1983 use alkalinity, rather than temperature and salinity to locate the plume region, because of upwelling in the region.

The irregular geometry of the plume and its layered structure were modelled as shown in Figure 12.

9.4 Calculated Radar Cross-section of Plume Boundary

The plume region was taken to have an average salinity in the upper 7.5 metres of 20°/oo at a temperature of 4°C. Below 7.5 metres salinity was taken to be 29°/oo at 4°C. Likewise the

region outside the plume was taken to be 29°/oo at 4°C.

This models the situation expected during ebb tide when the plume is fully extended into the St. Lawrence.

There is always uncertainty regarding the salinity of the plume because of its complex nature and the effect of fresh water runoff in the Saguenay. However unless the depth of plume, 7 1/2 metres, is grossly underestimated and the plume is far less saline than modelled the error in this modelling will not severely affect the surface impedance calculated for the plume.

Using the relationships for normalized surface impedance (section 3, equations 15 through 20) and the model described in section 9.2.1 the following sample of results was obtained (for a frequency of 25.4 MHz, antenna gains of 1.637, with a peak transmission power of 10 kW, characteristic of CODAR operations).

Range (see Fig. 12) Km	plume (cross-section) m^2
5	0.197
10	0.390
15	0.606
20	0.675

Comparison of theoretical first order cross-section in the same range cell as the plume will indicate whether the Doppler signal of the plume is likely to be identified in the Fourier transform (described in Section 5.2). Barrick, 1972, gives the average

cross-section per unit area, of the first order at 0.02 for vertical polarization and near grazing incidence.

The total first order cross-section (σ_{f_0}) is calculated from:

$$\sigma_{f_0} = \frac{\pi}{2} \left[(r + 600m) - (r - 600m)^2 \right] \times (0.02)$$

where r is the range in metres, and the plume boundary is assumed to lie in the middle of a range cell (see Figure 3)

The results are,

Range km		10 log $\left[\sigma_{plume}/\sigma_{f_0}\right]$
	m2	
5	3.77×10^5	-62.8 dB
10	7.54×10^5	-62.9 dB
15	1.13×10^6	-62.7 dB
20	1.51×10^6	-63.5 dB

The calculations indicate the plume's cross-section is of the order of 60 dB down from that of the expected first order in the same range cell.

The model assumed for the plume is probably optimistic in terms of the calculated cross-section. Firstly the change in salinity from the background to the plume will exist as a smooth gradient with distance rather than a sharp discontinuity as modelled. Secondly the plume will probably not exist as a straight line discontinuity exactly perpendicular to the radar boresight.

Considering the small cross-section of our plume model. and the fact that the model is probably optimistic, it is highly unlikely that the plume will be detected from the backscatter at its boundary.

The alternative is to determine if a surface current map would delineate the plume from the discontinuities in the surface currents. Practical surface current measurements in the region of a plume would demonstrate whether or not the surface currents effectively resolve the plume.

9.5 Calculation of Transmission Loss with Plume Present

The range of CODAR over a single medium can be estimated from the one way transmission loss (see Section 7). In this calculation of loss the attenuation function F(w) is used (see equation 14).

The range of CODAR looking into a plume (full plume conditions) is modelled in Figure 13. Medium (2) represents the region outside the plume (29°/oo, 4°C) and medium (1) represents the plume region (0 - 7.5 m, 20°/oo, 4°C; below 7.5m, 29°/oo, 4°C). Effectively the ability of CODAR to measure surface currents within the plume will be estimated. The result will be compared with CODAR's predicted range over a single medium (29°/oo, 4°C). In this fashion the reduction in range in the area of the plume will be examined. For the two media case the attenuation function "G" will be calculated from the model described in Section 9.2.2. Calculation of transmission loss still makes use of equation 14 but G is substituted for F(w).

Calculations were made for the case when the plume is 9.9 km from the radar (ie. in Figure 13 = 9.9 km). The results for both cases are shown in Table 6.

TABLE 6

|G| versus |F(w)|

Range (km)	G	Loss (Full Plume)
25.0	0.187	92.76 dB
26.0	0.177	93.58 dB
27.0	0.168	94.36 dB
28.0	0.159	95.15 dB
29.0	0.151	95.91 dB
30.0	0.144	96.61 dB
31.0	0.137	97.33 dB
32.0	0.131	97.99 dB
33.0	0.126	98.60 dB
34.0	0.120	99.28 dB

Range (km)	F(w)	Loss (No Plume)
31.5	0.184	94.9 dB
32.0	0.180	95.3 dB
33.0	0.173	95.8 dB
34.0	0.166	96.4 dB
35.0	0.160	97.1 dB
36.0	0.154	97.6 dB
37.0	0.148	98.2 dB
38.0	0.142	98.8 dB

The maximum tolerable one way transmission loss, from Section 7.1 was estimated to lie between 94.94 and 98.17 dB with a typical value of 96.6 dB. Locating these three loss figures in Table 3 the maximum range of CODAR can now be estimated, for the particular situation as described.

The maximum range for surface current mapping in the region outside the plume or during no plume conditions will be between 31.5 and 37 km, with a typical value of 34 km.

The maximum range extending into the plume region, when the plume boundary is approximately 10 km from the radar, will be between 28 and 32 km with a typical value of 30 km. Looking into the plume region the maximum range of CODAR is expected to be 4 km less than outside the plume.

10.0 SPECIFIC AREAS OF INTEREST; PROJECTED PERFORMANCE, OPERATIONAL CONSIDERATIONS

Three areas will be considered for potential CODAR surveys;

i) Entrances to Fury and Hecla Strait:

Approximate latitude: 69° 55'N

Approximate longitude: 82° 20', 85° 40'W

ii) Entrances to Bellot Strait:

Approximate Latitude: 72° N

Approximate Longitude: 94° 20', 95° 20'W

iii) Exit of Saquenay River into St. Lawrence river:

Approximate Latitude: 48° 08'N

Approximate Longitude: 69° 40'W

10.1 Seasonal Ice Coverage

Concern is given to time intervals when the area of interest can be considered relatively ice free ie. less than 1/10 coverage. Presence of icebergs and multiyear ice is not taken into consideration.

Based on information contained in "An Arctic Atlas", (1978) the following conclusions have been drawn concerning average ice conditions in the entrances of Fury and Hecla Strait and Bellot Strait.

Fury and Hecla Strait:

May to July: 10/10 ice coverage

August: 7/10 to 9/10

September: West entrance 4/10 - 9/10

East entrance 1/10 - 3/10

October: West entrance 7/10 - 9/10

East entrance 1/10 - 3/10

Bellot Strait:

Month	West Entrance	East Entrance
May	10/10	Landfast (100%)
June	7/10 - 9/10	7/10 - 9/10
July	10/10	7/10 - 9/10
August	4/10 - 6/10	1/10 - 3/10
September	less than 1/10	less than 1/10
October	10/10	7/10 - 9/10

Outlet of the Saguenay:

Based on Markham (1980) the following conclusions have been drawn concerning average ice conditions in the St. Lawrence at the exit of the Saguenay:

From June to mid-December, on average, the mouth of the Saguenay - St. Lawrence region should be ice free.

10.2 Preferred Arctic Location for Survey

Operational constraints such as anticipated ice coverage will favour one potential survey area over another. For example

the west entrance of Fury and Mecla Strait is indicated to have more average ice coverage during September than the east entrance. Given a choice, therefore, the east entrance would be preferable.

A CODAR survey to extract tidal components would require a time frame of days. During this time the survey region should be ice free. In addition the surrounding region should also be ice free to minimize the possibility of pack ice moving into the area of interest during the survey period.

The ice coverage in the east entrance of Fury and Hecla drops to between 1/10 to 3/10 during September and October. Conceivably the area could be ice free during an acceptable time period. The probable presence of pack ice in the vicinity, however, is difficult to accept.

By comparison, Bellot Strait in September has an average ice coverage less than 1/10 at both entrances. The area has a better chance of being ice free over a survey period. There is still the risk of pack ice in the vicinity, but on average, the nearby areas which still may have ice coverage are further removed from Bellot than from Fury and Hecla.

For these reasons Bellot Strait is preferred to Fury and Hecla. All that remains to decide is whether the east or west entrance is more appropriate.

This choice will be decided by available radar locations. Ideally the area of interest will lie mid way between the two CODAR systems. Each radar should sample the currents in the region from a significantly different look angle, ideally 90

degrees. The two measured radial components of a particular current can then be used to reconstruct the original current velocity with maximum accuracy. Figure 14 illustrates this point. Note that surface currents are not normally measured within 6 km of a radar site.

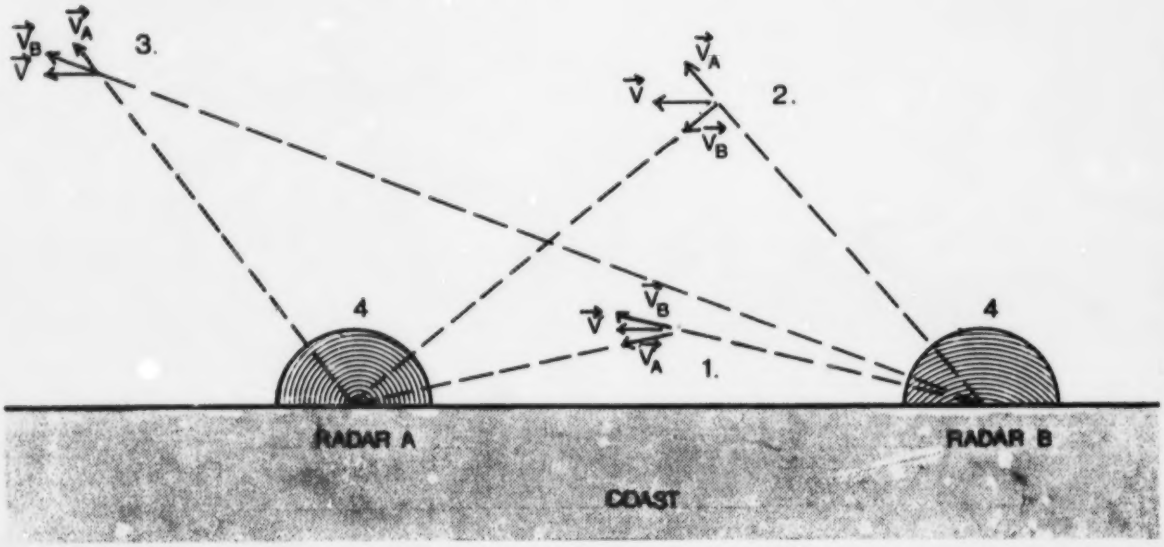

Figure 14 Consideration of Radar Location. Each CODAR site resolves a component of the surface current . Both components V_A (measured by CODAR A) and V_B (measured by CODAR B) are necessary to reconstruct V.

1) Currents lying near the coast between the radars are resolved into two components that are more parallel than orthogonal. Reconstruction of V will be sensitive to small errors in the magnitude of V_A, V_B.

2) In this region V is separated into orthogonal components and is less sensitive to small errors.

3) Some problems exist as in (1) with additional possibility that V_B may not be measured by Radar if range is too great.

4) No surface currents are measured within first 6 km of radar.

Since surface currents at the entrances are in the region of interest, this requires that both radars:

i) are more than 6 km from the entrances

ii) can be located to resolve the currents properly

iii) fields of view are not blocked by an obstruction such as a point of land between the radar and the area of interest.

The east entrance of Bellot Strait has two suitable radar locations satisfying these conditions. The west entrance, however, requires that one radar site be established on the shore of Somerset Island. This presents the situation of case (1) Figure 14 at the entrance to the Strait; the transmission path is shielded or blocked by land and this would prevent the radar from observing the water movement at the entrance.

The radar locations suggested for the east entrance are indicated in Figure 15.

The east entrance to Bellot Strait is considered the best area for a CODAR survey of surface currents.

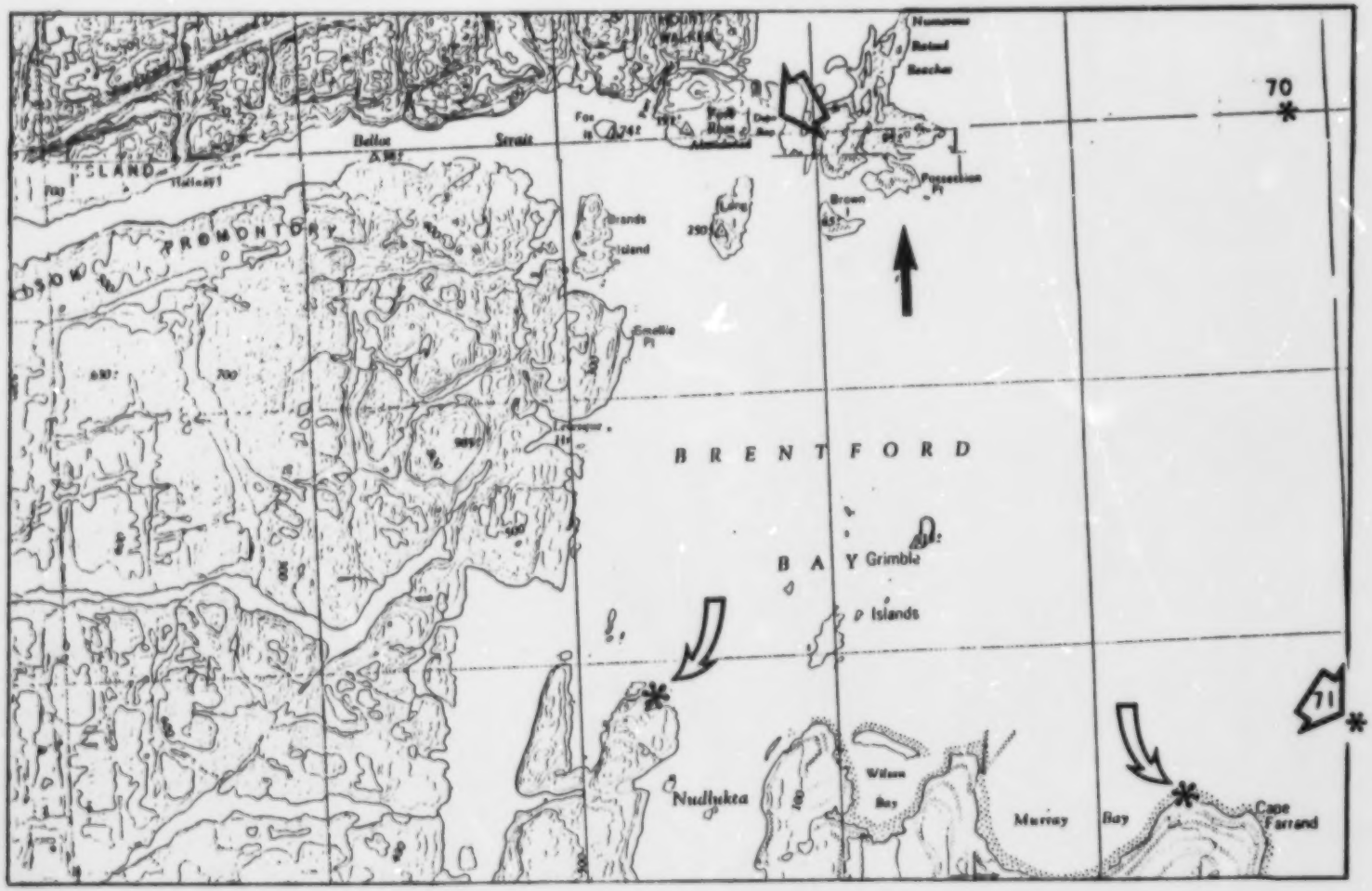

Figure 15 Suggested CODAR station locations for survey of East entrance to Bellot Strait. Map incorporates the UTM 10 km grid. Numbers 70 and 71 are water sample locations. The abandoned Fort Ross is also noted.

10.3 Projected Performance: East Entrance to Bellot Strait

Marine Environmental Data Service (MEDS) ran a search for any near surface salinity and temperature measurements recorded in the area of the eastern entrance during September. Only minimal information was obtained; two measurements made on September 8, 1962 (MEDS Cruise #181062359, stations 70 and 71) at 72° 00'N, 93° 40'W and 71° 47'N 93° 25'W, see Figure 15.

These measurements are really outside the area of interest. Both indicate a fairly uniform salinity of a depth of approximately 31°/oo @ 0°C. Therefore the projected performance in range will be optimistic if the salinity drops inside Brentford Bay.

For 31°/oo, 0°C, ice free conditions, the One Way Tolerable Transmission Loss figures (Section 7.1) and calculated loss indicate a range between 30.7 and 36.0 km with a typical range of 33.4 km.

Note that the distance (Fig. 15) between the site on the east side of Murray Bay and Long Island is approximately 15 n. miles or 27.8 km. A typical range of 30 km is predicted even when salinity (uniform) drops to 26°/oo @ 0°C. Therefore some overestimation of salinity can be tolerated.

10.4 Region of St. Lawrence near Outlet of Saguenay: Projected Performance

Unlike the Arctic, the region of interest in the St. Lawrence is ice free for approximately six months.

Salinity and temperature profiles of the St. Lawrence above and below the Saguenay are given by Reid, (1977), based on measurements in July, 1973. It is noted by Reid that in 1973 there was a large fresh water discharge through the St. Lawrence. Two lines of measurement were located approximately 5 n. miles, 9.2 km, above and below the Saguenay and stretched across most of the St. Lawrence running approximately southeast to northwest. The contours of constant salinity and/or temperature, given by Reid, are not flat but tend to slope, also forming hills and valleys. Modelling the area as a series of uniform layers of differing salinity and temperature is a simplification but is necessary if an estimate of radar range is to be calculated.

Using the information by Reid, five nautical miles, 9.2 km, above the Saguenay, the St. Lawrence, was modelled as an upper layer, 6°C, 25 to 27°/oo. 5 to 20m in depth over a uniform region, 4°C, 28‰. Five nautical miles, 9.2 km, below the Saguenay the St. Lawrence was modelled as an upper layer, 6°C, 27°/oo, 16 to 40m in depth over a uniform region, 2°C, 30°/oo.

One way transmission loss (flat earth model) was calculated for both cases. Loss was found to be independent of the upper layer thickness because of the minimum thickness scale involved (metres as opposed to cm) and the high conductivities of the upper layer and the region below.

Using the maximum tolerable one way transmission loss figures (Section 7.1), the expected ranges were estimated. In the region above the Saguenay the maximum range for current mapping should lie between 30.0 km and 35.0 km with a typical

value of 32 km. Below the Saguenay the maximum range should lie between 31.5 km and 36.8 km with a typical value of 34.2 km.

Section 9.5 derived the maximum range during plume and no plume conditions 31.5 to 37 km, typically 34 km (no plume) and 28 to 32 km, typically 30 km (plume), from salinity and temperature data recorded during November 1979 (Lebel, et al.). Some variability is to be expeccted in the estimated maximum range over the area of interest because of the varied salinity and temperature distributions.

The suggested radar locations (see Figure 16), are on the south shore of the St. Lawrence, near Ile du Gros Cacouna and St. Eloi Station. St.-Eloi-Station is approximately 33 km from Pointe Noire at the outlet of the Saquenay. Ile du Gros Cacouna is approximately 25 km from Pointe Noire. The St. Eloi Station field of view may be blocked by Ile Verte. If such is the case then that radar would probably have to be moved, possibly to the northeast end of Ile Verte, approximately 26 km from Pointe Noire.

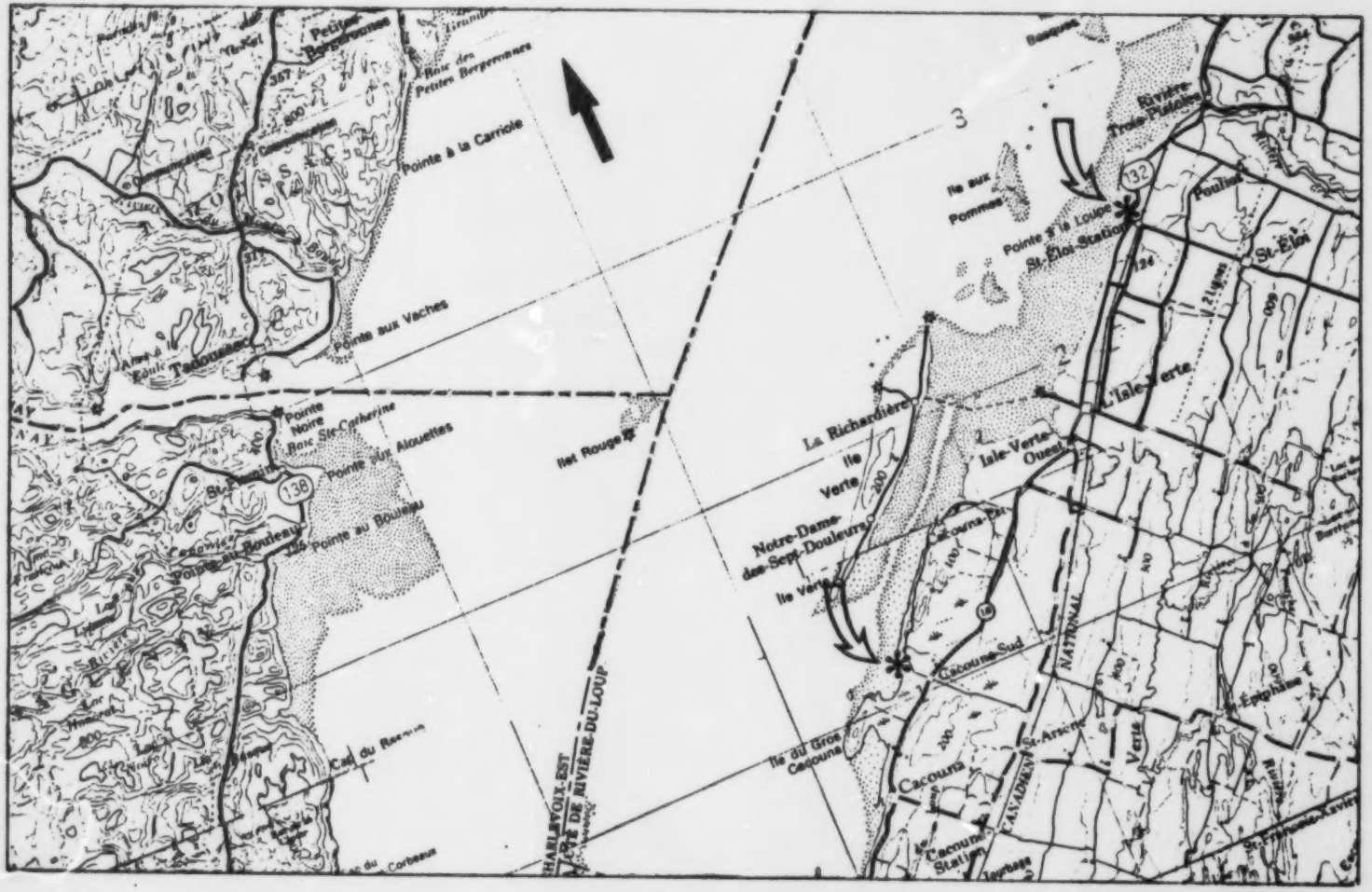

Figure 16 Suggested CODAR station locations for survey of Saguenay entering the St. Lawrence. Map incorporates the UTM 10 km grid. The black arrow is to establish true North for layout.

11.0 SUMMARY

Propagation loss measurements in the CODAR frequency range were compared with the results of a flat earth transmission loss model. The difference between observed and calculated loss is attributed to the effect of surface roughness (not included in the model). This difference generally agrees with published estimates of added loss due to surface roughness.

The maximum range of CODAR (single site) to map surface currents over sea water is extracted from a data set of surveys during which time wind velocities averaged almost 14 knots, 26 km/hr with variations in velocity from 0 to 20 knots, 37 km/hr. Consequently the maximum range figure reflects CODAR's range under actual operating conditions including surface roughness.

The maximum range figure is then translated into maximum tolerable basic one way transmission loss using the model. Over sea water CODAR's survey range was observed to be 36.5 km $\pm$ 2.9 km corresponding to a maximum tolerable loss lying between 94.9 dB and 98.2 dB, typically 96.6 dB.

From available theory, relationships were used to translate salinity and temperature into relative permittivity and conductivity. This permitted basic loss curves to be calculated (using the model) for a variety of salinities and temperatures.

The maximum tolerable loss figure and these new loss curves for less saline waters predict CODAR's range over brackish water.

Attention is then drawn to the severe reduction in range anticipated when significant sea ice coverage is present.

The plume of the Saguenay into the St. Lawrence is modelled in order to estimate the expected backscatter from the boundary. The backscatter was found to be insufficient to be detected reliably.

Lastly, three areas are considered for potential CODAR surveys; Bellot Strait, Fury and Hecla Strait, and the St. Lawrence at outlet of Saguenay.

Seasonal ice coverage caused Fury and Hecla to be rejected. Lack of available radar sites limit a potential survey to the east entrance of Bellot. Suggested radar locations are indicated. Based on sparse salinity data, maximum range (Bellot, east entrance) was calculated to lie between 30.7 km and 36.0 km with a typical value of 33.4 km. The time for this survey is probably restricted to September because of average ice conditions in the area. In addition the immediate area outside the survey region should also be ice free to minimize the risk of ice cover moving into the region during a survey.

The St. Lawrence Saguenay region is more amenable to survey because of its anticipated ice free interval, June to mid-December. The anticipated single site CODAR range is expected to vary because of the complex oceanography in the area. Predicted range is expected to lie between 28 and 37 km depending on plume conditions. The typical values to be expected and the sub-regions involved are given in Section 10.4. Radar sites are suggested with one alternate site available to compensate for possible obstruction of field of view.

REFERENCES

An Arctic Atlas: Background Information for Developing Marine Oilspill Countermeasures (1978). Environmental Protection Service, Fisheries and Environment Canada.

Barrick, D.E. (1970). The interaction of HF/VHF radio waves with the sea surface and its implications. AGARD Conf. Proc. Electromagnetics of the Sea, No. 77. Available from Clearing House for Federal Scientific and Technical Information, Springfield, Va., accession no. AD716305.

Barrick, D.E. (1971). Theory of HF and VHF propagation across the rough sea. I, The effective surface impedance for a slightly rough highly conducting medium at grazing incidence. Radio Science, Vol. 6, No. 5, pp. 517-526, May 1971.

Barrick, D.E. (1971). Application to HF and VHF propagation above the Sea. Radio Science, Vol. 6, No. 5. p. 517-526, p. 527-533.

Barrick, D.E. (1972). First Order Theory and Analysis of MF/HF/VHF Scatter from the Sea. IEEE Transactions on Antennas and Propagation Vol. AP-20 No. 1 January.

Barrick, D.E., Headrick, J.M., Bogle, R.W. and Crombie, D.D. (1974). Sea Backscatter at HF: Interpretation and Utilization of the Sea Echo. Proceedings of the IEEE, Vol. 62. No. 6, 1974.

Bedford Institute of Oceanography Report Series BI-R-77-1.

Bremmer, H. (1949). Terrestrial Radio Waves New York, N.Y.: Elsevier Publishing Co.

Butt, K.A. and Jeans, P.K. (1981). HF Radar Technology Transfer Project - Evaluation Phase. C-CORE Technical Report 81-14. October 1981, 136p.

Fock, V.A. (1965). Electromagnetic Diffraction and Propagation New York, N.Y.: Pergamon Press.

Hasted, J.B., Ritson, D.M., and Collie, C.H. (1948). Dielectric Properties of Aqueous Ionic Solutions. Parts I and II. The Journal of Chemical Physics Vol. 16, No. 1.

Jasik, H. (ed.) 1961. Antenna Engineering Handbook. New York: McGraw Hill.

Klein, K. and Butt. K.A. (1983). HF EM Propagation Over Horizontally Uniform First Year Sea Ice. C-CORE Technical Report 83-13. December 1983, 131 p.

Lane. J.A. and Saxton. J.A. (1952). Dielectric Dispersion in Pure Polar Liquids at Very High Radio Frequencies. Part III. The Effect of Electrolytes in Solution. Proc. Royal Society of London. Vol. 214. p. 531-545.

Lebel. J., Pelletier. E., Bergeron. M., Belzile. N. and Marquis. G. (1983). Le Panache du Saquenay. Can. J. Fish. Aquat. Sci. 40: 52-60.

Lorraine. P. and Corson. D.R. (1970). Electromagnetic Fields and Waves. Second Edition San Francisco: W.M. Freeman and Company.

Markham. W.E. (1980). Ice Atlas. Eastern Canadian Seaboard. Atmospheric Environment Service. Environment Canada. Toronto.

Reid. S.J. (1977). Circulation and Mixing in the St. Lawrence Estuary Near Ilet Rouge.

Saxton, J.A. and Lane. J.A. (1952). "Electrical Properties of Sea Water". Wireless Engineer. Vol. 29. P. 269-275.

Srivastava. S.K. (1984). Scattering of High-Frequency Electromagnetic Waves from an Ocean Surface: An Alternative Approach Incorporating a Dipole Source. Ph.D. Thesis. Memorial University of Newfoundland.

Wait. J.R., (1970). Electromagnetic Waves in Stratified Media. 2nd Edition (Chapter 2) New York: Pergamon Press.

Walsh. J. (1982). A General Theory of the Interaction of Electromagnetic Waves with Isotropic. Horizontally Layered Media and Applications to Propagation over Sea Ice. C-CORE Technical Report 82-9.

Walsh. J. (1983). Propagation and Scatter for Mixed Paths with Discontinuities and Applications to Remote Sensing of Sea Ice with HF Radar C-CORE Technical Report 83-16.

APPENDIX A

PROGRAM LISTING

COMPUTERIZED TRANSMISSION LOSS MODEL

```
!       ****************************************************************
!       **                        LAYPROP                             **
!       **                Written By : Joe Ryan                       **
!       **                Revised By : Ken Klein                      **
!       **                             Wayne Collins                  **
!       **             This Version Created : Dec 6,1983              **
!       ****************************************************************
!
!       This program computes the transmission loss with distance
!       of a vertically polarized H.F. E/M wave propogating over
!       a horozontally uniform semi-infinite medium, assuming an
!       infinitesimal dipole source, and receive antennas with
!       large separation, compared to the individual antenna
!       elevations, given: (1) Antenna Height (Transmitter and
!       Receiver), (2) Distance between transmitter and Receiver,
!       (3) Frequency, (4) Permittivity and Conductivity for each
!       layer, and (5) Number  of layers (The  lowest layer being
!       semi-infinite ). A graph of transmission loss vs.
!       distance can be plotted if desired.
!       This program requires two data files:
!
!                 Data File #1                        Data File #2
!       ------------------------------------      -----------------
!                                                   # of points
!                                                   Dist.(km),Loss(dB)
!       Permittivity layer n     [real]                   '
!       Conductivity layer n     [real]                   '
!       Thickness layer n (m)    [real]                   '
!       Permittivity layer n-1   [real]                   '
!       Conductivity layer n-1   [real]                   '
!       Thickness layer n-1 (m)  [real]                   '
!       etc.
!
!       Note: Data File #2 is required only when Observed Data is
!             to be plotted on the graph.
!
!XXXX
```

```
      DATE='05/12/83'     ! Version Date
  935 WRITE(5,199)' INPUT FILE NAME?            :'
      ACCEPT 203,FILE     ! selects data file.
      WRITE(5,199)' PRINTED DATA OUTPUT ?     (Y/N):'
      ACCEPT 190,TO
      IF(TO.NE.'Y'.AND.TO.NE.'y')GOTO 940
      WRITE(5,199)' PRINTED DATA OUTPUT FILE NAME?:'
      ACCEPT 203,TEROUT   ! Terminal Output
  940 WRITE(5,199)' PLOT GRAPH ?          (Y/N):'
      ACCEPT 190,GRPH
      IF(GRPH.NE.'Y'.AND.GRPH.NE.'y')GOTO 950
      WRITE(5,199)' DRAW AXIS ?           (Y/N):'
      ACCEPT 190,AXFLG
      WRITE(5,199)' LABEL CURVES ?        (Y/N):'
      ACCEPT 190,CLAB
      WRITE(5,199)' PLOT OBSERVED DATA ?  (Y/N):'
      ACCEPT 190,OBSERV
      WRITE(5,199)'GRAPH TITLE (20 CHARS.)?'
      READ(5,203)DATA
      IF(OBSERV.NE.'Y'.AND.OBSERV.NE.'y')GOTO 950
      WRITE(5,199)' OBSERVED DATA FILE NAME ? :'
      ACCEPT 203,TRUE     ! observed data

!XXXX
```

```
  980 DO 900 J=1,NRUNS
      WRITE(5,199)'HT. ANTENNA #1, M ?'
      ACCEPT *,H1
      WRITE(5,199)'HT. ANTENNA #2, M ?'
      ACCEPT *,H2
      WRITE(5,199)'FREQ. MHZ. ?'
      ACCEPT *,FRQ
        EOW=TOW*FRQ
        LAMDA=300./FRQ
        W=2*PI*FRQ*10**6
        MUOW=MUO*W
        CMUOW=CMPLX(0.,MUOW)
        WAVEN=W/(3*10**8)
      WRITE(5,199)'# OF LAYERS ?'
      ACCEPT *,NTHLYR
      WRITE(5,199)'CONDUCTIVITY OF SEMI INFINITE LAYER ?'
      ACCEPT *,CONDSE
      WRITE(5,199)'REL. PERM. OF SEMI INFINITE LAYER ?'
      ACCEPT *,PERMSE
      CALL INDATA(GRPH,NPOINT,DIST,START,H1,H2,FRQ,NTHLYR,NRUNS,
     +DATE,FILE,CONDSE,PERMSE)

          WRITE(5,199)' PERM. SCALE FACTOR ?'
          ACCEPT *,V1
          WRITE(5,199)' COND. SCALE FACTOR ?'
          ACCEPT *,V2
          WRITE(5,199)' THICK. SCALE FACTOR ?'
          ACCEPT *,V3
          IF(V3.EQ.1.0)GO TO 39
          WRITE(5,199)'LAYERS AFFECTED ? N TO N+M'
          ACCEPT *,M1,M2
   39     IF(GRPH.NE.'Y'.AND.GRPH.NE.'y')GOTO 990
          IF(CLAB.EQ.'Y'.OR.CLAB.EQ.'y')THEN
             WRITE(5,197)'  CURVE ',J,'  LABEL (15 CHARS.):'
             ACCEPT 202,LABEL   ! Curve Label for multiple curve plots
          ELSE
             LABEL='  '
          END IF
  990     IPEN=3
          D = START*1000.  ! converts from km. to m.

!    This loop (888) computes the normalized surface impedence
!    for each layer.

        G2=PERMSE*EOW
        CG2=CMPLX(CONDSE,G2)
        CGAM2=CMUOW*CG2
       IF(NTHLYR.LE.0.0)THEN
        ZEFF=CMUOW*CSQRT(CGAM2+WAVEN**2)/CGAM2
        CONDLR=CONDSE
        PERMLR=PERMSE
        CONST1=60.*LAMDA*CONDLR
        GO TO 888
       END IF
```

```
      DO 888 N=1,NTHLYR  ! first layer on top of sea water
         LAYERN=1+NTHLYR-N  ! nth layer=uppermost layer
               READ(3,10)PERMLR   ! set relative permittivity of layer
               READ(3,10)CONDLR   ! set conductivity of layer
               READ(3,10)THICK    ! set thickness of layer
               PERMLR=PERMLR*V1
               CONDLR=CONDLR*V2
               IF(V3.EQ.1.0)GO TO 220
               IF((LAYERN.LT.M1).OR.(LAYERN.GT.M2))GO TO 220
               THICK=THICK*V3
 220           IPERML=CONDLR/EOW  ! imaginary part of layer
                                  !    complex permittivity
         CPERML=CMPLX(PERMLR,-IPERML)  ! layer complex permittivity
         MGPERM=CABS(CPERML)! magnitude of layer complex
                                  !    permittivity
 77      G1=PERMLR*EOW      ! epsilon(layer) * omega
         CONST1=6.3*CONDLR*LAMDA

!    Calculate propagation consts.

         CG1=CMPLX(CONDLR,G1)
         CGAM1=CMUOW*CG1
         ZLAYER=CMUOW*CSQRT(CGAM1+WAVEN**2)/CGAM1
         !     =surface impedence of current layer
         IF(N.GT.1)GOTO 44! if lowest layer zbelow=Zsemi-infinite
         ZBELOW=CMUOW*CSQRT(CGAM2+WAVEN**2)/CGAM2
         !     =surface impedence of semi-infinite layer
  44     CTHICK=CMPLX(THICK,0.)
         T=CTHICK*CSQRT(CGAM1+WAVEN**2)
         TANHT=(CEXP(T)-CEXP(-T))/(CEXP(T)+CEXP(-T))
         !    =hyperbolic tangent of T
         IF(TO.EQ.'Y'.OR.TO.EQ.'y')CALL OUTPUT(ZLAYER,ZBELOW,T,
     +   TANHT,LAYERN,PERMLR,CONDLR,THICK,N)

!    Compute cumulative surface impedence layer by layer

         ZEFF=ZLAYER*(ZBELOW+ZLAYER*TANHT)/(ZLAYER+ZBELOW*TANHT)
         !   =effective surface impedence,
         !      including current layer
         ZBELOW=ZEFF  ! zbelow now includes current layer
 888 CONTINUE
         AZEFF=CABS(ZEFF)/377 ! normalized surface impedence.
         ZEFFN=ZEFF/Z0
      IF(TO.EQ.'Y'.OR.TO.EQ.'y')WRITE(1,93)ZEFFN

!XXXX
```

```
!    This loop (800) calculates 'phase','magnitude',
!    'transmission loss',and 'distance', for each point.

  889   DO 800 I=1,NPOINT
            THE=(4*PI*H1*H2)/(D*LAMDA) ! path length in rads (R1-R0)
            CON1=-PI*D/LAMDA
            CCON1=CMPLX(0.,CON1)
            SELANG=(H1+H2)/(SQRT(D**2+(H1+H2)**2))
!           Sin(theta)=z+h/R1
            CSEANG=CMPLX(SELANG,0.)
            P=(CCON1*(ZEFF/Z0)**2)*(1+Z0*CSEANG/ZEFF)**2
            ! P = Wait's 'W'
            IMAGP=AIMAG(P)
            REALP=REAL(P)
            B=ATAN2(IMAGP,REALP)  ! calculate argument of P
            MAGP=SQRT(IMAGP**2+REALP**2)  ! magnitude of P

!    Compute reflection coeff.

            RV=(CSEANG-ZEFFN)/(CSEANG+ZEFFN)
            ! = reflection coefficient, top layer

!    Calculate approximate attenuation function.

            CFTRM=CZERO  ! initializes first term asymptotic series
            CN1=CC1
            IF(MAGP.LE.10.)GOTO 120  ! yes = convergent series
                                     ! no = asymptotic series
            IF(B.LT.0.)GOTO 90! choose type of asymptotic series

!XXXX
```

```
!   Convergent series evaluation

  120       CAPSR=CZERO     ! initialize third term convergent series
            CN=CMPLX(1.,0.)
            CAPS1=CC1-C1*CSQRT(CPI*P)*CEXP(-P)
            !    =first and second terms in series
            CFACT(1)=CP2*P  ! general factor in series
            L=1             ! initialize term counter
  125       PCFAC=CFACT(L)
               L=L+1     ! increment to next term
               CN=CN+CP2 ! increment by 2
               CFACT(L)=(CFACT(1)/CN)*PCFAC ! (L+2)th term in series
               PCHEK=CABS(CFACT(L)) ! store magnitude of last term
               IF(PCHEK.GT.0.0001)GOTO 125 ! is last term significant
            DO 222 M=1,L    ! add terms (3) to (L+2)
               SI=(-CC1)**M ! sign function for alternating series
               CAPSR=CAPSR+SI*CFACT(M)
  222       CONTINUE
  250       FTERM=CAPS1+CAPSR  ! final value of series

!XXXX
```

```
          ! compute modulus of EZR
          EPHA=ATAN2(IEZR,REZR) ! compute argument of EZR
          CST=(EMAG*LAMDA*1.637)/(4*PI*D)
          LOSS=-20*(ALOG10(CST)+ALOG10(FACTOR)) ! calculate loss in dB.
          Y=1.+(175.-LOSS)*7./175  ! y-coordinate of graph.
          D2=D/1000.
          X=1.+(D2)/SCALE          ! x-coordinate of graph.
          IF(TO.NE.'Y'.AND.TO.NE.'y')GOTO 500
       MAGF=CABS(FTERM)
             WRITE(1,301) D,MAGP,EMAG,FACTOR,EPHA,LOSS,D,MAGF
500       D=D+((DIST-START)*1000.)/(NPOINT-1) ! increment dist
          IF(GRPH.NE.'Y'.AND.GRPH.NE.'y')GOTO 800
          CALL PLOT(X,Y,IPEN)
          IPEN=3+J
800     CONTINUE
        REWIND 3
        IF(GRPH.NE.'Y'.AND.GRPH.NE.'y')GOTO 900
        X2=X+1.0
        Y2=Y+(J*0.4)-0.8
        CALL PLOT(X2,Y2,IPEN)
        CALL SYMBOL(X2+.1,Y2-.025,.10,LABEL,0.,20)
900  CONTINUE
     CLOSE (UNIT=3)
     IF(TO.EQ.'Y'.OR.TO.EQ.'y')CLOSE (UNIT=1)
     IF(GRPH.NE.'Y'.AND.GRPH.NE.'y')GOTO 901
        IF(OBSERV.EQ.'Y'.OR.OBSERV.EQ.'y')CALL DATPLT(SCALE,TRUE)
        CALL PLOT(8.5,0.0,999)
901  CONTINUE
  10 FORMAT(F10.5)
  12 FORMAT(I1)
  13 FORMAT(X,I2)
  15 FORMAT(X,I1)
  45 FORMAT(X,F5.2)
  93 FORMAT('          NORMALIZED SURFACE IMPEDENCE =',
    +       F10.7,' +',F10.7,' i '//)
 111 FORMAT(' SURFACE IMPEDENCE ',F15.7)
 112 FORMAT(' MAGNITUDE OF COMPLEX PERMITTIVITY FOR LAYER ',
    +   I2,' = ',F10.7)
 190 FORMAT(A1)
 197 FORMAT($,A8,I2,A19)
 198 FORMAT($,A22)
 199 FORMAT($,A41)
 200 FORMAT($,A15)
 201 FORMAT(X,A20)
 202 FORMAT(A15)
 203 FORMAT(A20)
 301 FORMAT(F8.5,F12.3,4X,E10.5,1X,E10.5,1X,F12.6,1X,F9.2,F10.2,F12.6)
 305 FORMAT(2X,'NUMERICAL DISTANCE',9X,'ELECTRIC FIELD',21X
    +   ,'LOSS',3X,'DISTANCE',3X,'MAGNITUDE OF F(W)')
 306 FORMAT(' PHASE (RAD)',2X,'MAGNTD',6X,'MAGNTD',6X,'FACTOR',
    +   9X,'PHASE',6X,'(DB)',3X,'(METERS)'//)
 801 STOP
     END
```

```
      SUBROUTINE GRAPH(SCALE,NCHRS,DATA,DATE)
!        Subroutine to draw and label the axis for the graph
         CHARACTER*20 DATA,DATE
            CALL AXIS (1.,1.,'DISTANCE(KM)',-12,10.,0.,SCALE)
            CALL AXIS (1.,1.,'TRANSMISSION LOSS(DB)',21,7.,90.,
     +      175.,-25.)
            CALL SYMBOL (4.1,7.75,.15,DATA,0.,20)
            CALL SYMBOL (4.2,7.25,.15,'Version Date:',0.,13)
            CALL SYMBOL (6.6,7.25,.15,DATE,0.,15)
      RETURN
      END

!XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

      SUBROUTINE DATPLT(SCALE,TRUE)
!        Subroutine to plot observed data on graph
         CHARACTER*20 TRUE
         INTEGER I,NCHRS,COUNT,NPOINT
         REAL DIS(20),DB(20),ERRDIS(20),ERRDB(20)
         OPEN(UNIT=2,NAME=TRUE,TYPE='OLD')
         READ(2,69) NPOINT
         DO 18 COUNT=1,NPOINT
            READ(2,*)DIS(COUNT),ERRDIS(COUNT),DB(COUNT),ERRDB(COUNT)
            X=1.+(DIS(COUNT))/SCALE
            Y=1.+(175.-DB(COUNT))*7./175
            EX=ERRDIS(COUNT)/SCALE
            EY=ERRDB(COUNT)*7./175.
            CALL PLOT((X-EX),Y,3)
            CALL PLOT((X+EX),Y,2)
            CALL PLOT(X,(Y-EY),3)
            CALL PLOT(X,(Y+EY),2)
   18    CONTINUE
         CALL SYMBOL(4.35,7.0,.15,'- Observed data points',0.0,22)
         CLOSE (UNIT=2)
   69    FORMAT(I3)
      RETURN
      END

!XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

```
      SUBROUTINE OUTPUT(ZLAYER,ZBELOW,T,TANHT,LAYERN,
     + PERMLR,CONDLR,THICK,N)
            COMPLEX ZLAYER,ZBELOW,T,TANHT
            INTEGER LAYERN,N
            IF(N.GT.1) GO TO 601
            WRITE(1,667)
  601       WRITE(1,600)LAYERN,PERMLR,CONDLR,THICK,ZBELOW,ZLAYER
  600       FORMAT(2X,I2,3X,F6.3,3X,F8.5,2X,F6.3,2X,F6.2,' + ',
     + F6.2,' I ',2X,F6.2,' + ',F6.2,' I')
  667       FORMAT(' LAYER',2X,'REL.PER',2X,'COND',4X,'THICK',5X,
     + 'Z BELOW LAYER',7X,'ZLAYER ONLY')
       RETURN
       END

!XXXX
```

APPENDIX B

TABULATED ONE WAY PATH LOSS VERSUS RANGE FOR BRACKISH WATER

```
VERSION DATE      = ! 05/12/83
DATA FILE         = ! sesmat.dat
GRAPH ? (Y/N)     = ! n
NUMBER OF POINTS  =   60
DISTANCE          =    39.50
STARTING POINT    =    33.50
TRANSMITTER HEIGHT=     0.00
RECEIVER HEIGHT   =     0.00
FREQUENCY         =    25.40
NUMBER OF LAYERS  =   0
NUMBER OF RUNS    =   1
  REL. PERM. (BOTTOM)=  75.7200
       COND. (BOTTOM)=   2.9800
         NORMALIZED SURFACE IMPEDENCE = 0.0156588 + 0.0150995 i
```

NUMERICAL DISTANCE PHASE (RAD)	MAGNTD	ELECTRIC FIELD MAGNTD	FACTOR	PHASE	LOSS (DB)	DISTANCE (METERS)	MAGNITUDE OF F(W)
0.03636	4.216	.39273E+00	.10000E+01	-2.824286	94.88	33500.00	0.196366
0.03636	4.229	.39120E+00	.10000E+01	-2.826238	94.94	33601.70	0.195601
0.03636	4.242	.38967E+00	.10000E+01	-2.828173	95.00	33703.39	0.194836
0.03636	4.255	.38814E+00	.10000E+01	-2.830092	95.06	33805.09	0.194075
0.03636	4.268	.38663E+00	.10000E+01	-2.832003	95.12	33906.78	0.193317
0.03636	4.280	.38513E+00	.10000E+01	-2.833907	95.18	34008.48	0.192567
0.03636	4.293	.38363E+00	.10000E+01	-2.835788	95.24	34110.17	0.191817
0.03636	4.306	.38214E+00	.10000E+01	-2.837668	95.30	34211.87	0.191074
0.03636	4.319	.38065E+00	.10000E+01	-2.839526	95.36	34313.56	0.190331
0.03636	4.332	.37919E+00	.10000E+01	-2.841389	95.42	34415.26	0.189601
0.03636	4.344	.37773E+00	.10000E+01	-2.843225	95.47	34516.95	0.188867
0.03636	4.357	.37628E+00	.10000E+01	-2.845056	95.53	34618.65	0.188141
0.03636	4.370	.37482E+00	.10000E+01	-2.846869	95.59	34720.34	0.187415
0.03636	4.383	.37339E+00	.10000E+01	-2.848683	95.65	34822.04	0.186699
0.03636	4.396	.37194E+00	.10000E+01	-2.850377	95.71	34923.73	0.185974
0.03636	4.408	.37051E+00	.10000E+01	-2.852145	95.77	35025.43	0.185258
0.03636	4.421	.36910E+00	.10000E+01	-2.853921	95.83	35127.13	0.184553
0.03636	4.434	.36769E+00	.10000E+01	-2.855680	95.89	35228.82	0.183851
0.03636	4.447	.36628E+00	.10000E+01	-2.857414	95.94	35330.52	0.183144
0.03636	4.460	.36490E+00	.10000E+01	-2.859151	96.00	35432.21	0.182451
0.03636	4.472	.36351E+00	.10000E+01	-2.860876	96.06	35533.91	0.181759
0.03636	4.485	.36213E+00	.10000E+01	-2.862587	96.12	35635.60	0.181069
0.03636	4.498	.36077E+00	.10000E+01	-2.864295	96.18	35737.30	0.180390
0.03636	4.511	.35940E+00	.10000E+01	-2.865970	96.23	35838.99	0.179705
0.03636	4.524	.35805E+00	.10000E+01	-2.867634	96.29	35940.69	0.179030
0.03636	4.536	.35670E+00	.10000E+01	-2.869321	96.35	36042.38	0.178353
0.03636	4.549	.35536E+00	.10000E+01	-2.870978	96.40	36144.08	0.177685
0.03636	4.562	.35404E+00	.10000E+01	-2.872634	96.46	36245.77	0.177024
0.03636	4.575	.35271E+00	.10000E+01	-2.874269	96.52	36347.47	0.176358

NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(W)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
0.03636	4.588	.35140E+00	.10000E+01	-2.875902	96.58	36449.16	0.175705
0.03636	4.600	.35007E+00	.10000E+01	-2.877490	96.63	36550.86	0.175039
0.03636	4.613	.34878E+00	.10000E+01	-2.879110	96.69	36652.55	0.174392
0.03636	4.626	.34749E+00	.10000E+01	-2.880708	96.74	36754.25	0.173747
0.03636	4.639	.34620E+00	.10000E+01	-2.882283	96.80	36855.95	0.173101
0.03636	4.652	.34491E+00	.10000E+01	-2.883851	96.86	36957.64	0.172456
0.03636	4.664	.34365E+00	.10000E+01	-2.885431	96.91	37059.34	0.171829
0.03636	4.677	.34237E+00	.10000E+01	-2.886971	96.97	37161.03	0.171188
0.03636	4.690	.34110E+00	.10000E+01	-2.888508	97.03	37262.73	0.170555
0.03636	4.703	.33986E+00	.10000E+01	-2.890043	97.08	37364.42	0.169932
0.03636	4.716	.33860E+00	.10000E+01	-2.891554	97.14	37466.12	0.169305
0.03636	4.728	.33740E+00	.10000E+01	-2.893197	97.19	37567.81	0.168700
0.03636	4.741	.33616E+00	.10000E+01	-2.894702	97.25	37669.51	0.168084
0.03636	4.754	.33495E+00	.10000E+01	-2.896215	97.30	37771.20	0.167480
0.03636	4.767	.33372E+00	.10000E+01	-2.897687	97.36	37872.90	0.166862
0.03636	4.780	.33252E+00	.10000E+01	-2.899174	97.41	37974.59	0.166262
0.03636	4.792	.33130E+00	.10000E+01	-2.900634	97.47	38076.29	0.165653
0.03636	4.805	.33010E+00	.10000E+01	-2.902095	97.52	38177.98	0.165053
0.03636	4.818	.32891E+00	.10000E+01	-2.903542	97.58	38279.68	0.164459
0.03636	4.831	.32773E+00	.10000E+01	-2.904987	97.63	38381.37	0.163869
0.03636	4.844	.32656E+00	.10000E+01	-2.906430	97.68	38483.07	0.163281
0.03636	4.856	.32539E+00	.10000E+01	-2.907852	97.74	38584.77	0.162699
0.03636	4.869	.32421E+00	.10000E+01	-2.909247	97.79	38686.46	0.162108
0.03636	4.882	.32305E+00	.10000E+01	-2.910658	97.85	38788.16	0.161530
0.03636	4.895	.32191E+00	.10000E+01	-2.912057	97.90	38889.85	0.160959
0.03636	4.908	.32076E+00	.10000E+01	-2.913443	97.95	38991.55	0.160383
0.03636	4.920	.31961E+00	.10000E+01	-2.914806	98.01	39093.24	0.159809
0.03636	4.933	.31848E+00	.10000E+01	-2.916189	98.06	39194.94	0.159244
0.03636	4.946	.31735E+00	.10000E+01	-2.917536	98.11	39296.63	0.158679
0.03636	4.959	.31624E+00	.10000E+01	-2.918908	98.17	39398.33	0.158123
0.03636	4.972	.31512E+00	.10000E+01	-2.920232	98.22	39500.02	0.157564

```
VERSION DATE      = ! 05/12/83
DATA FILE         = ! SEAWAT.DAT
GRAPH ? (Y/N)     = ! N
NUMBER OF POINTS  =   60
DISTANCE          =    45.00
STARTING POINT    =     0.10
TRANSMITTER HEIGHT=     0.00
RECEIVER HEIGHT   =     0.00
FREQUENCY         =    25.40
NUMBER OF LAYERS  =   0
NUMBER OF RUNS    =   6
  REL. PERM. (BOTTOM)=  79.5370
       COND. (BOTTOM)=   0.1364
         NORMALIZED SURFACE IMPEDENCE = 0.0807237 + 0.0377776 i
```

NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(W)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
0.69538	0.211	.14162E+01	.10000E+01	-0.710256	33.24	100.00	0.711690
0.69538	1.819	.58313E+00	.10000E+01	-1.679683	59.64	861.02	0.293049
0.69538	3.427	.34310E+00	.10000E+01	-1.997451	69.75	1622.03	0.172425
0.69538	5.035	.23341E+00	.10000E+01	-2.152354	76.44	2383.05	0.117298
0.69538	6.643	.17367E+00	.10000E+01	-2.238235	81.41	3144.07	0.087276
0.69538	8.251	.13706E+00	.10000E+01	-2.288238	85.35	3905.09	0.068879
0.69538	9.859	.11081E+00	.10000E+01	-2.328053	88.74	4666.10	0.055689
0.69538	11.467	.95710E-01	.10000E+01	-2.343248	91.33	5427.12	0.048099
0.69538	13.075	.83228E-01	.10000E+01	-2.360611	93.68	6188.14	0.041826
0.69538	14.683	.73383E-01	.10000E+01	-2.372690	95.78	6949.15	0.036879
0.69538	16.291	.65618E-01	.10000E+01	-2.381984	97.66	7710.17	0.032976
0.69538	17.898	.59392E-01	.10000E+01	-2.391278	99.34	8471.19	0.029847
0.69538	19.506	.54190E-01	.10000E+01	-2.396821	100.89	9232.20	0.027233
0.69538	21.114	.49827E-01	.10000E+01	-2.401456	102.30	9993.22	0.025040
0.69538	22.722	.46114E-01	.10000E+01	-2.405386	103.61	10754.24	0.023174
0.69538	24.330	.42916E-01	.10000E+01	-2.408759	104.83	11515.25	0.021567
0.69538	25.938	.40133E-01	.10000E+01	-2.411684	105.97	12276.27	0.020169
0.69538	27.546	.37688E-01	.10000E+01	-2.414244	107.04	13037.29	0.018940
0.69538	29.154	.35525E-01	.10000E+01	-2.416505	108.04	13798.30	0.017853
0.69538	30.762	.33596E-01	.10000E+01	-2.418514	108.99	14559.32	0.016884
0.69538	32.370	.31866E-01	.10000E+01	-2.420310	109.90	15320.34	0.016014
0.69538	33.978	.30305E-01	.10000E+01	-2.421926	110.75	16081.35	0.015230
0.69538	35.586	.28891E-01	.10000E+01	-2.423389	111.57	16842.37	0.014519
0.69538	37.194	.27602E-01	.10000E+01	-2.424720	112.35	17603.39	0.013871
0.69538	38.801	.26423E-01	.10000E+01	-2.425932	113.10	18364.41	0.013279
0.69538	40.409	.25341E-01	.10000E+01	-2.427045	113.81	19125.42	0.012735
0.69538	42.017	.24344E-01	.10000E+01	-2.428066	114.50	19886.44	0.012234
0.69538	43.625	.23423E-01	.10000E+01	-2.429009	115.16	20647.46	0.011771
0.69538	45.233	.22569E-01	.10000E+01	-2.429883	115.80	21408.48	0.011342
0.69538	46.841	.21774E-01	.10000E+01	-2.430693	116.41	22169.49	0.010943

NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(M)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
0.69538	48.449	.21034E-01	.10000E+01	-2.431448	117.01	22930.51	0.010571
0.69538	50.057	.20343E-01	.10000E+01	-2.432149	117.58	23691.53	0.010223
0.69538	51.665	.19695E-01	.10000E+01	-2.432807	118.14	24452.55	0.009898
0.69538	53.273	.19088E-01	.10000E+01	-2.433422	118.68	25213.56	0.009593
0.69538	54.881	.18517E-01	.10000E+01	-2.434005	119.20	25974.58	0.009305
0.69538	56.489	.17979E-01	.10000E+01	-2.434546	119.70	26735.60	0.009035
0.69538	58.097	.17471E-01	.10000E+01	-2.435061	120.20	27496.62	0.008780
0.69538	59.705	.16991E-01	.10000E+01	-2.435547	120.68	28257.63	0.008539
0.69538	61.312	.16537E-01	.10000E+01	-2.436002	121.14	29018.65	0.008311
0.69538	62.920	.16107E-01	.10000E+01	-2.436439	121.60	29779.67	0.008094
0.69538	64.528	.15698E-01	.10000E+01	-2.436851	122.04	30540.69	0.007889
0.69538	66.136	.15310E-01	.10000E+01	-2.437239	122.47	31301.71	0.007694
0.69538	67.744	.14940E-01	.10000E+01	-2.437614	122.89	32062.72	0.007508
0.69538	69.352	.14588E-01	.10000E+01	-2.437964	123.30	32823.74	0.007331
0.69538	70.960	.14252E-01	.10000E+01	-2.438301	123.70	33584.75	0.007162
0.69538	72.568	.13931E-01	.10000E+01	-2.438626	124.10	34345.77	0.007001
0.69538	74.176	.13624E-01	.10000E+01	-2.438930	124.48	35106.79	0.006847
0.69538	75.784	.13331E-01	.10000E+01	-2.439228	124.85	35867.80	0.006699
0.69538	77.392	.13048E-01	.10000E+01	-2.440110	125.22	36628.82	0.006557
0.69538	79.000	.12779E-01	.10000E+01	-2.440359	125.58	37389.83	0.006422
0.69538	80.608	.12520E-01	.10000E+01	-2.440595	125.94	38150.85	0.006292
0.69538	82.215	.12272E-01	.10000E+01	-2.440818	126.28	38911.86	0.006167
0.69538	83.823	.12033E-01	.10000E+01	-2.441041	126.62	39672.88	0.006047
0.69538	85.431	.11804E-01	.10000E+01	-2.441248	126.95	40433.89	0.005932
0.69538	87.039	.11583E-01	.10000E+01	-2.441453	127.28	41194.91	0.005821
0.69538	88.647	.11370E-01	.10000E+01	-2.441643	127.60	41955.93	0.005714
0.69538	90.255	.11165E-01	.10000E+01	-2.441837	127.91	42716.94	0.005611
0.69538	91.863	.10967E-01	.10000E+01	-2.442019	128.22	43477.96	0.005511
0.69538	93.471	.10776E-01	.10000E+01	-2.442191	128.52	44238.97	0.005415
0.69538	95.079	.10592E-01	.10000E+01	-2.442362	128.82	44999.99	0.005323

```
VERSION DATE      = : 05/12/83
DATA FILE         = : SEAWAT.DAT
GRAPH ? (Y/N)     = : N
NUMBER OF POINTS  =   60
DISTANCE          =    45.00
STARTING POINT    =     0.10
TRANSMITTER HEIGHT=     0.00
RECEIVER HEIGHT   =     0.00
FREQUENCY         =    25.40
NUMBER OF LAYERS  =    0
NUMBER OF RUNS    =    6
  REL. PERM. (BOTTOM)=  78.0730
       COND. (BOTTOM)=   0.8176
         NORMALIZED SURFACE IMPEDENCE = 0.0311566 + 0.0271884 i
```

NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(W)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
0.13582	0.045	.19119E+01	.10000E+01	-0.373393	30.63	100.00	0.956177
0.13582	0.392	.15785E+01	.10000E+01	-1.065654	50.99	861.02	0.789435
0.13582	0.738	.13379E+01	.10000E+01	-1.426251	57.93	1622.03	0.669119
0.13582	1.084	.11457E+01	.10000E+01	-1.688100	62.62	2383.05	0.572997
0.13582	1.430	.98842E+00	.10000E+01	-1.894361	66.31	3144.07	0.494322
0.13582	1.776	.85800E+00	.10000E+01	-2.063018	69.42	3905.09	0.429101
0.13582	2.122	.74912E+00	.10000E+01	-2.203670	72.15	4666.10	0.374648
0.13582	2.468	.65765E+00	.10000E+01	-2.322330	74.59	5427.12	0.328903
0.13582	2.815	.58043E+00	.10000E+01	-2.423078	76.81	6188.14	0.290282
0.13582	3.161	.51503E+00	.10000E+01	-2.508876	78.86	6949.15	0.257572
0.13582	3.507	.45936E+00	.10000E+01	-2.582033	80.76	7710.17	0.229731
0.13582	3.853	.41189E+00	.10000E+01	-2.644378	82.52	8471.19	0.205993
0.13582	4.199	.37118E+00	.10000E+01	-2.697441	84.17	9232.20	0.185634
0.13582	4.545	.33626E+00	.10000E+01	-2.742524	85.72	9993.22	0.168170
0.13582	4.891	.30609E+00	.10000E+01	-2.780698	87.17	10754.24	0.153082
0.13582	5.237	.28005E+00	.10000E+01	-2.813041	88.54	11515.25	0.140057
0.13582	5.584	.25734E+00	.10000E+01	-2.840218	89.83	12276.27	0.128700
0.13582	5.930	.23763E+00	.10000E+01	-2.863303	91.04	13037.29	0.118845
0.13582	6.276	.22027E+00	.10000E+01	-2.882573	92.19	13798.30	0.110161
0.13582	6.622	.20507E+00	.10000E+01	-2.898820	93.28	14559.32	0.102561
0.13582	6.968	.19160E+00	.10000E+01	-2.912349	94.32	15320.34	0.095820
0.13582	7.314	.17976E+00	.10000E+01	-2.923138	95.29	16081.35	0.089902
0.13582	7.660	.16909E+00	.10000E+01	-2.933586	96.22	16842.37	0.084563
0.13582	8.006	.15962E+00	.10000E+01	-2.941100	97.11	17603.39	0.079826
0.13582	8.353	.15104E+00	.10000E+01	-2.948872	97.95	18364.41	0.075540
0.13582	8.699	.14307E+00	.10000E+01	-2.954316	98.73	19125.42	0.071952
0.13582	9.045	.13707E+00	.10000E+01	-2.961221	99.49	19886.44	0.068549
0.13582	9.391	.13023E+00	.10000E+01	-2.960543	100.26	20647.46	0.065142
0.13582	9.737	.12506E+00	.10000E+01	-2.967446	100.93	21408.48	0.062547
0.13582	10.083	.11939E+00	.10000E+01	-2.973011	101.63	22169.49	0.059707

NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(W)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
0.13582	10.429	.11450E+00	.10000E+01	-2.975034	102.29	22930.51	0.057262
0.13582	10.776	.10992E+00	.10000E+01	-2.977636	102.93	23691.53	0.054971
0.13582	11.122	.10579E+00	.10000E+01	-2.979111	103.53	24452.55	0.052909
0.13582	11.468	.10197E+00	.10000E+01	-2.980448	104.12	25213.56	0.050999
0.13582	11.814	.98427E-01	.10000E+01	-2.981667	104.69	25974.58	0.049225
0.13582	12.160	.95044E-01	.10000E+01	-2.983424	105.24	26735.60	0.047533
0.13582	12.506	.91971E-01	.10000E+01	-2.984365	105.77	27496.62	0.045996
0.13582	12.852	.89093E-01	.10000E+01	-2.985237	106.28	28257.63	0.044557
0.13582	13.198	.86393E-01	.10000E+01	-2.986047	106.78	29018.65	0.043206
0.13582	13.545	.83853E-01	.10000E+01	-2.986801	107.27	29779.67	0.041936
0.13582	13.891	.81460E-01	.10000E+01	-2.987504	107.74	30540.69	0.040739
0.13582	14.237	.79201E-01	.10000E+01	-2.988162	108.19	31301.71	0.039610
0.13582	14.583	.77066E-01	.10000E+01	-2.988779	108.64	32062.72	0.038542
0.13582	14.929	.75043E-01	.10000E+01	-2.989357	109.08	32823.74	0.037530
0.13582	15.275	.73125E-01	.10000E+01	-2.989902	109.50	33584.75	0.036571
0.13582	15.621	.71304E-01	.10000E+01	-2.990415	109.91	34345.77	0.035660
0.13582	15.967	.69522E-01	.10000E+01	-2.991310	110.32	35106.79	0.034769
0.13582	16.314	.67878E-01	.10000E+01	-2.991735	110.72	35867.80	0.033947
0.13582	16.660	.66310E-01	.10000E+01	-2.992138	111.10	36628.82	0.033163
0.13582	17.006	.64813E-01	.10000E+01	-2.992522	111.48	37389.83	0.032414
0.13582	17.352	.63383E-01	.10000E+01	-2.992888	111.85	38150.85	0.031699
0.13582	17.698	.62015E-01	.10000E+01	-2.993236	112.21	38911.86	0.031014
0.13582	18.044	.60704E-01	.10000E+01	-2.993569	112.56	39672.88	0.030359
0.13582	18.390	.59449E-01	.10000E+01	-2.993886	112.91	40433.89	0.029731
0.13582	18.736	.58244E-01	.10000E+01	-2.994190	113.25	41194.91	0.029129
0.13582	19.083	.57088E-01	.10000E+01	-2.994480	113.58	41955.93	0.028550
0.13582	19.429	.55976E-01	.10000E+01	-2.994759	113.91	42716.94	0.027994
0.13582	19.775	.54907E-01	.10000E+01	-2.995025	114.23	43477.96	0.027460
0.13582	20.121	.53879E-01	.10000E+01	-2.995281	114.55	44238.97	0.026946
0.13582	20.467	.52888E-01	.10000E+01	-2.995527	114.85	44999.99	0.026450

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VERSION DATE      = ; 05/12/83
DATA FILE         = ; SEAMAT.DAT
GRAPH ? (Y/N)     = ; N
NUMBER OF POINTS  =   60
DISTANCE          =    45.00
STARTING POINT    =     0.10
TRANSMITTER HEIGHT=     0.00
RECEIVER HEIGHT   =     0.00
FREQUENCY         =    25.40
NUMBER OF LAYERS  =    0
NUMBER OF RUNS    =    6
  REL. PERM. (BOTTOM)=  76.6090
       COND. (BOTTOM)=   1.4989
         NORMALIZED SURFACE IMPEDENCE = 0.0224431 + 0.0208611 i
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NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(W)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
0.07303	0.025	.19585E+01	.10000E+01	-0.279738	30.42	100.00	0.979341
0.07303	0.215	.17723E+01	.10000E+01	-0.807273	49.99	861.02	0.886231
0.07303	0.405	.16196E+01	.10000E+01	-1.094150	56.27	1622.03	0.809844
0.07303	0.595	.14851E+01	.10000E+01	-1.310507	60.36	2383.05	0.742612
0.07303	0.785	.13650E+01	.10000E+01	-1.487835	63.50	3144.07	0.682542
0.07303	0.975	.12569E+01	.10000E+01	-1.639110	66.10	3905.09	0.628489
0.07303	1.165	.11592E+01	.10000E+01	-1.771201	68.35	4666.10	0.579655
0.07303	1.355	.10708E+01	.10000E+01	-1.888259	70.35	5427.12	0.535420
0.07303	1.545	.99045E+00	.10000E+01	-1.993111	72.17	6188.14	0.495259
0.07303	1.735	.91743E+00	.10000E+01	-2.087696	73.84	6949.15	0.458744
0.07303	1.925	.85096E+00	.10000E+01	-2.173427	75.40	7710.17	0.425508
0.07303	2.116	.79037E+00	.10000E+01	-2.251505	76.86	8471.19	0.395211
0.07303	2.306	.73509E+00	.10000E+01	-2.322771	78.24	9232.20	0.367572
0.07303	2.496	.68463E+00	.10000E+01	-2.387900	79.54	9993.22	0.342340
0.07303	2.686	.63852E+00	.10000E+01	-2.447541	80.79	10754.24	0.319280
0.07303	2.876	.59633E+00	.10000E+01	-2.502280	81.97	11515.25	0.298187
0.07303	3.066	.55774E+00	.10000E+01	-2.552377	83.11	12276.27	0.278888
0.07303	3.256	.52239E+00	.10000E+01	-2.598305	84.20	13037.29	0.261212
0.07303	3.446	.48998E+00	.10000E+01	-2.640469	85.25	13798.30	0.245006
0.07303	3.636	.46026E+00	.10000E+01	-2.679084	86.26	14559.32	0.230146
0.07303	3.826	.43299E+00	.10000E+01	-2.714315	87.23	15320.34	0.216510
0.07303	4.016	.40793E+00	.10000E+01	-2.746560	88.17	16081.35	0.203981
0.07303	4.206	.38490E+00	.10000E+01	-2.776186	89.08	16842.37	0.192464
0.07303	4.396	.36372E+00	.10000E+01	-2.803045	89.95	17603.39	0.181874
0.07303	4.586	.34422E+00	.10000E+01	-2.827555	90.80	18364.41	0.172121
0.07303	4.776	.32625E+00	.10000E+01	-2.849991	91.62	19125.42	0.163134
0.07303	4.966	.30968E+00	.10000E+01	-2.870401	92.41	19886.44	0.154852
0.07303	5.156	.29439E+00	.10000E+01	-2.888714	93.18	20647.46	0.147205
0.07303	5.346	.28026E+00	.10000E+01	-2.905338	93.92	21408.48	0.140141
0.07303	5.536	.26722E+00	.10000E+01	-2.920764	94.64	22169.49	0.133621

NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(N)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
0.07303	5.726	.25511E+00	.10000E+01	-2.934518	95.33	22930.51	0.127563
0.07303	5.916	.24388E+00	.10000E+01	-2.946696	96.01	23691.53	0.121950
0.07303	6.107	.23346E+00	.10000E+01	-2.958025	96.66	24452.55	0.116738
0.07303	6.297	.22375E+00	.10000E+01	-2.968187	97.29	25213.56	0.111882
0.07303	6.487	.21483E+00	.10000E+01	-2.977072	97.91	25974.58	0.107422
0.07303	6.677	.20652E+00	.10000E+01	-2.985242	98.50	26735.60	0.103269
0.07303	6.867	.19852E+00	.10000E+01	-2.992352	99.09	27496.62	0.099267
0.07303	7.057	.19133E+00	.10000E+01	-2.999377	99.64	28257.63	0.095673
0.07303	7.247	.18457E+00	.10000E+01	-3.005393	100.19	29018.65	0.092291
0.07303	7.437	.17824E+00	.10000E+01	-3.010182	100.72	29779.67	0.089127
0.07303	7.627	.17203E+00	.10000E+01	-3.014258	101.24	30540.69	0.086020
0.07303	7.817	.16683E+00	.10000E+01	-3.019883	101.72	31301.71	0.083421
0.07303	8.007	.16088E+00	.10000E+01	-3.023178	102.25	32062.72	0.080445
0.07303	8.197	.15619E+00	.10000E+01	-3.025019	102.71	32823.74	0.078102
0.07303	8.387	.15200E+00	.10000E+01	-3.029924	103.14	33584.75	0.076006
0.07303	8.577	.14764E+00	.10000E+01	-3.032179	103.59	34345.77	0.073825
0.07303	8.767	.14360E+00	.10000E+01	-3.039379	104.02	35106.79	0.071807
0.07303	8.957	.13849E+00	.10000E+01	-3.034913	104.52	35867.80	0.069249
0.07303	9.147	.13549E+00	.10000E+01	-3.035977	104.90	36628.82	0.067749
0.07303	9.337	.13214E+00	.10000E+01	-3.034437	105.29	37389.83	0.066074
0.07303	9.527	.12876E+00	.10000E+01	-3.046886	105.69	38150.85	0.064382
0.07303	9.717	.12632E+00	.10000E+01	-3.043780	106.03	38911.86	0.063165
0.07303	9.908	.12129E+00	.10000E+01	-3.035897	106.55	39672.88	0.060649
0.07303	10.098	.11956E+00	.10000E+01	-3.050819	106.84	40433.89	0.059783
0.07303	10.288	.11681E+00	.10000E+01	-3.051441	107.21	41194.91	0.058407
0.07303	10.478	.11418E+00	.10000E+01	-3.052024	107.56	41955.93	0.057095
0.07303	10.668	.11168E+00	.10000E+01	-3.052570	107.91	42716.94	0.055843
0.07303	10.858	.10918E+00	.10000E+01	-3.053527	108.26	43477.96	0.054592
0.07303	11.048	.10690E+00	.10000E+01	-3.053968	108.59	44238.97	0.053454
0.07303	11.238	.10472E+00	.10000E+01	-3.054385	108.92	44999.99	0.052363

```
VERSION DATE      = : 05/12/83
DATA FILE         = : SEAWAT.DAT
GRAPH ? (Y/N)     = : N
NUMBER OF POINTS  =   60
DISTANCE          =    45.00
STARTING POINT    =     0.10
TRANSMITTER HEIGHT=     0.00
RECEIVER HEIGHT   =     0.00
FREQUENCY         =    25.40
NUMBER OF LAYERS  =   0
NUMBER OF RUNS    =   6
  REL. PERM. (BOTTOM)=  73.6820
       COND. (BOTTOM)=   2.8600
         NORMALIZED SURFACE IMPEDENCE = 0.0159877 + 0.0154087 i
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NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(W)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
-0.03688	0.013	.19813E+01	.10000E+01	-0.203102	30.32	100.00	0.990684
-0.03688	0.113	.18851E+01	.10000E+01	-0.591030	49.45	861.02	0.942575
-0.03688	0.213	.17997E+01	.10000E+01	-0.806258	55.35	1622.03	0.899868
-0.03688	0.313	.17201E+01	.10000E+01	-0.971605	59.09	2383.05	0.860072
-0.03688	0.412	.16452E+01	.10000E+01	-1.109695	61.88	3144.07	0.822620
-0.03688	0.512	.15744E+01	.10000E+01	-1.229802	64.15	3905.09	0.787222
-0.03688	0.612	.15074E+01	.10000E+01	-1.336817	66.07	4666.10	0.753689
-0.03688	0.712	.14437E+01	.10000E+01	-1.433707	67.76	5427.12	0.721871
-0.03688	0.812	.13833E+01	.10000E+01	-1.522403	69.27	6188.14	0.691656
-0.03688	0.911	.13258E+01	.10000E+01	-1.604309	70.65	6949.15	0.662933
-0.03688	1.011	.12712E+01	.10000E+01	-1.680443	71.91	7710.17	0.635610
-0.03688	1.111	.12192E+01	.10000E+01	-1.751533	73.09	8471.19	0.609610
-0.03688	1.211	.11697E+01	.10000E+01	-1.818254	74.20	9232.20	0.584859
-0.03688	1.311	.11226E+01	.10000E+01	-1.880992	75.25	9993.22	0.561290
-0.03688	1.410	.10777E+01	.10000E+01	-1.940207	76.24	10754.24	0.538836
-0.03688	1.510	.10349E+01	.10000E+01	-1.996204	77.19	11515.25	0.517440
-0.03688	1.610	.99408E+00	.10000E+01	-2.049311	78.09	12276.27	0.497049
-0.03688	1.710	.95520E+00	.10000E+01	-2.099693	78.96	13037.29	0.477609
-0.03688	1.810	.91813E+00	.10000E+01	-2.147552	79.80	13798.30	0.459073
-0.03688	1.909	.88278E+00	.10000E+01	-2.193102	80.60	14559.32	0.441396
-0.03688	2.009	.84905E+00	.10000E+01	-2.236481	81.38	15320.34	0.424534
-0.03688	2.109	.81689E+00	.10000E+01	-2.277859	82.14	16081.35	0.408451
-0.03688	2.209	.78619E+00	.10000E+01	-2.317309	82.87	16842.37	0.393104
-0.03688	2.309	.75691E+00	.10000E+01	-2.354963	83.59	17603.39	0.378460
-0.03688	2.408	.72896E+00	.10000E+01	-2.390922	84.28	18364.41	0.364484
-0.03688	2.508	.70226E+00	.10000E+01	-2.425200	84.96	19125.42	0.351136
-0.03688	2.608	.67678E+00	.10000E+01	-2.457984	85.62	19886.44	0.338397
-0.03688	2.708	.65245E+00	.10000E+01	-2.489302	86.26	20647.46	0.326231
-0.03688	2.808	.62923E+00	.10000E+01	-2.519300	86.89	21408.48	0.314623
-0.03688	2.907	.60705E+00	.10000E+01	-2.547930	87.51	22169.49	0.303532

NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(W)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
-0.03688	3.007	.58586E+00	.10000E+01	-2.573299	88.11	22930.51	0.292938
-0.03688	3.107	.56561E+00	.10000E+01	-2.601386	89.70	23691.53	0.282809
-0.03688	3.207	.54626E+00	.10000E+01	-2.626355	89.28	24452.55	0.273135
-0.03688	3.307	.52777E+00	.10000E+01	-2.650207	89.84	25213.56	0.263892
-0.03688	3.406	.51012E+00	.10000E+01	-2.673060	90.39	25974.58	0.255066
-0.03688	3.506	.49324E+00	.10000E+01	-2.694849	90.94	26735.60	0.246625
-0.03688	3.606	.47710E+00	.10000E+01	-2.715656	91.47	27496.62	0.238554
-0.03688	3.706	.46168E+00	.10000E+01	-2.735538	91.99	28257.63	0.230843
-0.03688	3.806	.44689E+00	.10000E+01	-2.754388	92.51	29018.65	0.223448
-0.03688	3.905	.43277E+00	.10000E+01	-2.772451	93.01	29779.67	0.216391
-0.03688	4.005	.41926E+00	.10000E+01	-2.789665	93.51	30540.69	0.209636
-0.03688	4.105	.40637E+00	.10000E+01	-2.806177	93.99	31301.71	0.203187
-0.03688	4.205	.39401E+00	.10000E+01	-2.821853	94.47	32062.72	0.197008
-0.03688	4.305	.38218E+00	.10000E+01	-2.836794	94.94	32823.74	0.191095
-0.03688	4.404	.37084E+00	.10000E+01	-2.850930	95.40	33584.75	0.185426
-0.03688	4.504	.35999E+00	.10000E+01	-2.864428	95.85	34345.77	0.179999
-0.03688	4.604	.34961E+00	.10000E+01	-2.877272	96.29	35106.79	0.174809
-0.03688	4.704	.33967E+00	.10000E+01	-2.889481	96.73	35867.80	0.169838
-0.03688	4.804	.33016E+00	.10000E+01	-2.901225	97.16	36628.82	0.165084
-0.03688	4.903	.32105E+00	.10000E+01	-2.912299	97.58	37389.83	0.160527
-0.03688	5.003	.31232E+00	.10000E+01	-2.922824	98.00	38150.85	0.156161
-0.03688	5.103	.30392E+00	.10000E+01	-2.932669	98.40	38911.86	0.151960
-0.03688	5.203	.29585E+00	.10000E+01	-2.942076	98.81	39672.88	0.147930
-0.03688	5.303	.28812E+00	.10000E+01	-2.950987	99.20	40433.89	0.144065
-0.03688	5.402	.28076E+00	.10000E+01	-2.959468	99.59	41194.91	0.140383
-0.03688	5.502	.27367E+00	.10000E+01	-2.967650	99.97	41955.93	0.136839
-0.03688	5.602	.26688E+00	.10000E+01	-2.975293	100.34	42716.94	0.133441
-0.03688	5.702	.26037E+00	.10000E+01	-2.982580	100.71	43477.96	0.130186
-0.03688	5.802	.25406E+00	.10000E+01	-2.989192	101.07	44238.97	0.127032
-0.03688	5.901	.24808E+00	.10000E+01	-2.995729	101.43	44999.99	0.124041

```
VERSION DATE      = : 05/12/83
DATA FILE         = : SEAWAT.DAT
GRAPH ? (Y/N)     = : N
NUMBER OF POINTS  =   60
DISTANCE          =   45.00
STARTING POINT    =    0.10
TRANSMITTER HEIGHT=    0.00
RECEIVER HEIGHT   =    0.00
FREQUENCY         =   25.40
NUMBER OF LAYERS  =   0
NUMBER OF RUNS    =   6
  REL. PERM. (BOTTOM)=  72.2180
       COND. (BOTTOM)=   3.5400
         NORMALIZED SURFACE IMPEDENCE = 0.0143190 + 0.0139067 i
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NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(W)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
-0.02922	0.011	.19856E+01	.10000E+01	-0.182621	30.30	100.00	0.992819
-0.02922	0.091	.19085E+01	.10000E+01	-0.532304	49.34	861.02	0.954274
-0.02922	0.172	.18389E+01	.10000E+01	-0.727072	55.17	1622.03	0.919436
-0.02922	0.253	.17731E+01	.10000E+01	-0.877238	58.83	2383.05	0.886565
-0.02922	0.333	.17106E+01	.10000E+01	-1.003097	61.54	3144.07	0.855286
-0.02922	0.414	.16508E+01	.10000E+01	-1.112963	63.74	3905.09	0.825411
-0.02922	0.495	.15936E+01	.10000E+01	-1.211214	65.59	4666.10	0.796820
-0.02922	0.575	.15388E+01	.10000E+01	-1.300517	67.21	5427.12	0.769416
-0.02922	0.656	.14863E+01	.10000E+01	-1.382605	68.65	6188.14	0.743135
-0.02922	0.736	.14358E+01	.10000E+01	-1.458702	69.95	6949.15	0.717915
-0.02922	0.817	.13874E+01	.10000E+01	-1.529723	71.15	7710.17	0.693696
-0.02922	0.898	.13408E+01	.10000E+01	-1.596347	72.27	8471.19	0.670432
-0.02922	0.978	.12961E+01	.10000E+01	-1.659129	73.31	9232.20	0.648075
-0.02922	1.059	.12532E+01	.10000E+01	-1.718477	74.29	9993.22	0.626587
-0.02922	1.140	.12118E+01	.10000E+01	-1.774750	75.22	10754.24	0.605928
-0.02922	1.220	.11721E+01	.10000E+01	-1.828242	76.10	11515.25	0.586062
-0.02922	1.301	.11339E+01	.10000E+01	-1.879162	76.95	12276.27	0.566957
-0.02922	1.382	.10971E+01	.10000E+01	-1.927763	77.76	13037.29	0.548578
-0.02922	1.462	.10618E+01	.10000E+01	-1.974206	78.53	13798.30	0.530895
-0.02922	1.543	.10278E+01	.10000E+01	-2.018675	79.28	14559.32	0.513883
-0.02922	1.624	.99501E+00	.10000E+01	-2.061261	80.01	15320.34	0.497511
-0.02922	1.704	.96350E+00	.10000E+01	-2.102103	80.71	16081.35	0.481754
-0.02922	1.785	.93317E+00	.10000E+01	-2.141309	81.39	16842.37	0.466588
-0.02922	1.866	.90396E+00	.10000E+01	-2.178927	82.05	17603.39	0.451985
-0.02922	1.946	.87583E+00	.10000E+01	-2.215109	82.69	18364.41	0.437928
-0.02922	2.027	.84870E+00	.10000E+01	-2.249903	83.31	19125.42	0.424393
-0.02922	2.108	.82271E+00	.10000E+01	-2.283377	83.92	19886.44	0.411359
-0.02922	2.188	.79762E+00	.10000E+01	-2.315654	84.52	20647.46	0.398816
-0.02922	2.269	.77345E+00	.10000E+01	-2.346702	85.10	21408.48	0.386731
-0.02922	2.349	.75018E+00	.10000E+01	-2.376612	85.67	22169.49	0.375092

NUMERICAL DISTANCE PHASE (RAD)	NUMERICAL DISTANCE MAGNTD	ELECTRIC FIELD MAGNTD	ELECTRIC FIELD FACTOR	ELECTRIC FIELD PHASE	LOSS (DB)	DISTANCE (METERS)	MAGNITUDE OF F(N)
-0.02922	2.430	.72774E+00	.10000E+01	-2.405389	86.23	22930.51	0.363875
-0.02922	2.511	.70614E+00	.10000E+01	-2.433148	86.77	23691.53	0.353074
-0.02922	2.591	.68532E+00	.10000E+01	-2.459899	87.31	24452.55	0.342666
-0.02922	2.672	.66527E+00	.10000E+01	-2.485684	87.83	25213.56	0.332639
-0.02922	2.753	.64596E+00	.10000E+01	-2.510592	88.34	25974.58	0.322986
-0.02922	2.833	.62735E+00	.10000E+01	-2.534571	88.85	26735.60	0.313678
-0.02922	2.914	.60941E+00	.10000E+01	-2.557697	89.34	27496.62	0.304711
-0.02922	2.995	.59213E+00	.10000E+01	-2.579998	89.83	28257.63	0.296069
-0.02922	3.075	.57545E+00	.10000E+01	-2.601440	90.31	29018.65	0.287729
-0.02922	3.156	.55939E+00	.10000E+01	-2.622151	90.78	29779.67	0.279698
-0.02922	3.237	.54390E+00	.10000E+01	-2.642104	91.24	30540.69	0.271952
-0.02922	3.317	.52896E+00	.10000E+01	-2.661333	91.70	31301.71	0.264484
-0.02922	3.398	.51459E+00	.10000E+01	-2.679933	92.15	32062.72	0.257298
-0.02922	3.479	.50072E+00	.10000E+01	-2.697814	92.59	32823.74	0.250362
-0.02922	3.559	.48734E+00	.10000E+01	-2.715043	93.02	33584.75	0.243673
-0.02922	3.640	.47444E+00	.10000E+01	-2.731644	93.45	34345.77	0.237223
-0.02922	3.721	.46197E+00	.10000E+01	-2.747564	93.87	35106.79	0.230990
-0.02922	3.801	.44996E+00	.10000E+01	-2.762935	94.29	35867.80	0.224985
-0.02922	3.882	.43838E+00	.10000E+01	-2.777733	94.70	36628.82	0.219193
-0.02922	3.962	.42720E+00	.10000E+01	-2.791971	95.10	37389.83	0.213604
-0.02922	4.043	.41641E+00	.10000E+01	-2.805657	95.50	38150.85	0.208209
-0.02922	4.124	.40605E+00	.10000E+01	-2.818941	95.89	38911.86	0.203026
-0.02922	4.204	.39602E+00	.10000E+01	-2.831644	96.27	39672.88	0.198012
-0.02922	4.285	.38633E+00	.10000E+01	-2.843845	96.65	40433.89	0.193166
-0.02922	4.366	.37696E+00	.10000E+01	-2.855596	97.03	41194.91	0.188494
-0.02922	4.446	.36792E+00	.10000E+01	-2.866765	97.40	41955.93	0.183964
-0.02922	4.527	.35921E+00	.10000E+01	-2.877578	97.76	42716.94	0.179607
-0.02922	4.608	.35079E+00	.10000E+01	-2.887955	98.12	43477.96	0.175399
-0.02922	4.688	.34266E+00	.10000E+01	-2.897902	98.48	44238.97	0.171331
-0.02922	4.769	.33484E+00	.10000E+01	-2.907573	98.82	44999.99	0.167423

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VERSION DATE      = : 05/12/83
DATA FILE         = : SEAMAT.DAT
GRAPH ? (Y/N)     = : N
NUMBER OF POINTS  =   60
DISTANCE          =    45.00
STARTING POINT    =     0.10
TRANSMITTER HEIGHT=     0.00
RECEIVER HEIGHT   =     0.00
FREQUENCY         =    25.40
NUMBER OF LAYERS  =   0
NUMBER OF RUNS    =   6
  REL. PERM. (BOTTOM)=  69.2900
       COND. (BOTTOM)=   4.9050
         NORMALIZED SURFACE IMPEDENCE = 0.0121128 + 0.0118700 i
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NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(W)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
-0.02025	0.008	.19903E+01	.10000E+01	-0.155186	30.28	100.00	0.995162
-0.02025	0.066	.19355E+01	.10000E+01	-0.453179	49.22	861.02	0.967737
-0.02025	0.124	.18848E+01	.10000E+01	-0.619887	54.95	1622.03	0.942387
-0.02025	0.182	.18362E+01	.10000E+01	-0.748937	58.52	2383.05	0.918109
-0.02025	0.241	.17894E+01	.10000E+01	-0.857534	61.15	3144.07	0.894700
-0.02025	0.299	.17441E+01	.10000E+01	-0.952718	63.26	3905.09	0.872060
-0.02025	0.357	.17003E+01	.10000E+01	-1.038187	65.03	4666.10	0.850137
-0.02025	0.415	.16577E+01	.10000E+01	-1.116190	66.56	5427.12	0.828879
-0.02025	0.473	.16165E+01	.10000E+01	-1.188201	67.92	6188.14	0.808254
-0.02025	0.532	.15765E+01	.10000E+01	-1.255266	69.14	6949.15	0.788230
-0.02025	0.590	.15376E+01	.10000E+01	-1.318132	70.26	7710.17	0.768788
-0.02025	0.648	.14998E+01	.10000E+01	-1.377383	71.30	8471.19	0.749903
-0.02025	0.706	.14631E+01	.10000E+01	-1.433471	72.26	9232.20	0.731555
-0.02025	0.765	.14274E+01	.10000E+01	-1.486740	73.16	9993.22	0.713729
-0.02025	0.823	.13928E+01	.10000E+01	-1.537509	74.01	10754.24	0.696401
-0.02025	0.881	.13591E+01	.10000E+01	-1.586010	74.82	11515.25	0.679557
-0.02025	0.939	.13264E+01	.10000E+01	-1.632446	75.59	12276.27	0.663183
-0.02025	0.997	.12945E+01	.10000E+01	-1.677013	76.32	13037.29	0.647261
-0.02025	1.056	.12636E+01	.10000E+01	-1.719828	77.02	13798.30	0.631780
-0.02025	1.114	.12334E+01	.10000E+01	-1.761034	77.70	14559.32	0.616726
-0.02025	1.172	.12042E+01	.10000E+01	-1.800744	78.35	15320.34	0.602085
-0.02025	1.230	.11757E+01	.10000E+01	-1.839056	78.98	16081.35	0.587846
-0.02025	1.288	.11480E+01	.10000E+01	-1.876028	79.59	16842.37	0.573994
-0.02025	1.347	.11210E+01	.10000E+01	-1.911787	80.18	17603.39	0.560522
-0.02025	1.405	.10948E+01	.10000E+01	-1.946380	80.75	18364.41	0.547415
-0.02025	1.463	.10693E+01	.10000E+01	-1.979871	81.31	19125.42	0.534664
-0.02025	1.521	.10445E+01	.10000E+01	-2.012344	81.85	19886.44	0.522262
-0.02025	1.580	.10204E+01	.10000E+01	-2.043808	82.38	20647.46	0.510194
-0.02025	1.638	.99690E+00	.10000E+01	-2.074327	82.90	21408.48	0.498451
-0.02025	1.696	.97405E+00	.10000E+01	-2.103946	83.40	22169.49	0.487026

NUMERICAL DISTANCE PHASE (RAD)	DISTANCE MAGNTD	ELECTRIC FIELD MAGNTD	FACTOR	PHASE	LOSS (DB)	DISTANCE (METERS)	MAGNITUDE OF F(W)
-0.02025	1.754	.95181E+00	.10000E+01	-2.132706	83.89	22930.51	0.475909
-0.02025	1.812	.93017E+00	.10000E+01	-2.160609	84.38	23691.53	0.465087
-0.02025	1.871	.90911E+00	.10000E+01	-2.187741	84.85	24452.55	0.454557
-0.02025	1.929	.88862E+00	.10000E+01	-2.214112	85.32	25213.56	0.444311
-0.02025	1.987	.86867E+00	.10000E+01	-2.239750	85.77	25974.58	0.434338
-0.02025	2.045	.84926E+00	.10000E+01	-2.264680	86.22	26735.60	0.424631
-0.02025	2.104	.83036E+00	.10000E+01	-2.288928	86.66	27496.62	0.415183
-0.02025	2.162	.81199E+00	.10000E+01	-2.312567	87.09	28257.63	0.405996
-0.02025	2.220	.79409E+00	.10000E+01	-2.335540	87.51	29018.65	0.397048
-0.02025	2.278	.77667E+00	.10000E+01	-2.357899	87.93	29779.67	0.388338
-0.02025	2.336	.75971E+00	.10000E+01	-2.379666	88.34	30540.69	0.379859
-0.02025	2.395	.74321E+00	.10000E+01	-2.400862	88.75	31301.71	0.371607
-0.02025	2.453	.72712E+00	.10000E+01	-2.421453	89.15	32062.72	0.363563
-0.02025	2.511	.71147E+00	.10000E+01	-2.441537	89.54	32823.74	0.355738
-0.02025	2.569	.69624E+00	.10000E+01	-2.461096	89.93	33584.75	0.348121
-0.02025	2.628	.68140E+00	.10000E+01	-2.480143	90.31	34345.77	0.340704
-0.02025	2.686	.66696E+00	.10000E+01	-2.498688	90.68	35106.79	0.333481
-0.02025	2.744	.65292E+00	.10000E+01	-2.516798	91.05	35867.80	0.326460
-0.02025	2.802	.63923E+00	.10000E+01	-2.534407	91.42	36628.82	0.319616
-0.02025	2.860	.62590E+00	.10000E+01	-2.551560	91.78	37389.83	0.312953
-0.02025	2.919	.61292E+00	.10000E+01	-2.568266	92.14	38150.85	0.306464
-0.02025	2.977	.60029E+00	.10000E+01	-2.584542	92.49	38911.86	0.300146
-0.02025	3.035	.58799E+00	.10000E+01	-2.600400	92.84	39672.88	0.293995
-0.02025	3.093	.57598E+00	.10000E+01	-2.615786	93.18	40433.89	0.287989
-0.02025	3.152	.56429E+00	.10000E+01	-2.630808	93.52	41194.91	0.282149
-0.02025	3.210	.55292E+00	.10000E+01	-2.645443	93.86	41955.93	0.276463
-0.02025	3.268	.54184E+00	.10000E+01	-2.659690	94.19	42716.94	0.270924
-0.02025	3.326	.53105E+00	.10000E+01	-2.673561	94.52	43477.96	0.265527
-0.02025	3.384	.52057E+00	.10000E+01	-2.687122	94.84	44238.97	0.260285
-0.02025	3.443	.51033E+00	.10000E+01	-2.700284	95.16	44999.99	0.255168

```
VERSION DATE      = : 05/12/83
DATA FILE         = : SEAWAT.DAT
GRAPH ? (Y/N).    = : N
NUMBER OF POINTS  =   60
DISTANCE          =    45.00
STARTING POINT    =     0.10
TRANSMITTER HEIGHT=     0.00
RECEIVER HEIGHT   =     0.00
FREQUENCY         =    25.40
NUMBER OF LAYERS  =   0
NUMBER OF RUNS    =   6
  REL. PERM. (BOTTOM)=  75.7200
       COND. (BOTTOM)=   2.9800
         NORMALIZED SURFACE IMPEDENCE = 0.0156588 + 0.0150995 i
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NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(W)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
0.03636	0.013	.19820E+01	.10000E+01	-0.198975	30.32	100.00	0.991034
0.03636	0.108	.18895E+01	.10000E+01	-0.579190	49.43	861.02	0.944748
0.03636	0.204	.18071E+01	.10000E+01	-0.790296	55.32	1622.03	0.903587
0.03636	0.300	.17303E+01	.10000E+01	-0.952592	59.04	2383.05	0.865154
0.03636	0.396	.16578E+01	.10000E+01	-1.088225	61.62	3144.07	0.828923
0.03636	0.492	.15892E+01	.10000E+01	-1.206277	64.07	3905.09	0.794614
0.03636	0.587	.15241E+01	.10000E+01	-1.311554	65.98	4666.10	0.762043
0.03636	0.683	.14621E+01	.10000E+01	-1.406936	67.65	5427.12	0.731083
0.03636	0.779	.14032E+01	.10000E+01	-1.494330	69.15	6188.14	0.701626
0.03636	0.875	.13471E+01	.10000E+01	-1.575098	70.51	6949.15	0.673571
0.03636	0.970	.12937E+01	.10000E+01	-1.650220	71.76	7710.17	0.646836
0.03636	1.066	.12427E+01	.10000E+01	-1.720483	72.93	8471.19	0.621345
0.03636	1.162	.11940E+01	.10000E+01	-1.786433	74.02	9232.20	0.597034
0.03636	1.258	.11477E+01	.10000E+01	-1.848536	75.06	9993.22	0.573841
0.03636	1.354	.11034E+01	.10000E+01	-1.907208	76.03	10754.24	0.551705
0.03636	1.449	.10611E+01	.10000E+01	-1.962753	76.97	11515.25	0.530574
0.03636	1.545	.10208E+01	.10000E+01	-2.015471	77.86	12276.27	0.510397
0.03636	1.641	.98224E+00	.10000E+01	-2.065552	78.72	13037.29	0.491127
0.03636	1.737	.94543E+00	.10000E+01	-2.113210	79.54	13798.30	0.472721
0.03636	1.832	.91025E+00	.10000E+01	-2.158582	80.34	14559.32	0.455134
0.03636	1.928	.87664E+00	.10000E+01	-2.201866	81.11	15320.34	0.438329
0.03636	2.024	.84452E+00	.10000E+01	-2.243172	81.85	16081.35	0.422268
0.03636	2.120	.81383E+00	.10000E+01	-2.282662	82.57	16842.37	0.406920
0.03636	2.216	.78448E+00	.10000E+01	-2.320383	83.28	17603.39	0.392247
0.03636	2.311	.75642E+00	.10000E+01	-2.356454	83.96	18364.41	0.378217
0.03636	2.407	.72959E+00	.10000E+01	-2.390966	84.63	19125.42	0.364803
0.03636	2.503	.70392E+00	.10000E+01	-2.423923	85.28	19886.44	0.351966
0.03636	2.599	.67937E+00	.10000E+01	-2.455506	85.91	20647.46	0.339692
0.03636	2.695	.65589E+00	.10000E+01	-2.485731	86.53	21408.48	0.327950
0.03636	2.790	.63344E+00	.10000E+01	-2.514734	87.14	22169.49	0.316725

NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(U)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
0.03636	2.886	.61195E+00	.10000E+01	-2.542464	87.73	22930.51	0.305980
0.03636	2.982	.59138E+00	.10000E+01	-2.569020	88.31	23691.33	0.295697
0.03636	3.078	.57169E+00	.10000E+01	-2.594387	88.88	24452.35	0.285849
0.03636	3.173	.55284E+00	.10000E+01	-2.618708	89.44	25213.56	0.276427
0.03636	3.269	.53480E+00	.10000E+01	-2.641983	89.98	25974.58	0.267405
0.03636	3.365	.51752E+00	.10000E+01	-2.664251	90.52	26735.60	0.258767
0.03636	3.461	.50101E+00	.10000E+01	-2.685638	91.05	27496.62	0.250510
0.03636	3.557	.48518E+00	.10000E+01	-2.706080	91.56	28257.63	0.242593
0.03636	3.652	.47001E+00	.10000E+01	-2.725621	92.07	29018.65	0.235010
0.03636	3.748	.45547E+00	.10000E+01	-2.744230	92.57	29779.67	0.227741
0.03636	3.844	.44154E+00	.10000E+01	-2.762060	93.06	30540.69	0.220775
0.03636	3.940	.42821E+00	.10000E+01	-2.779110	93.54	31301.71	0.214108
0.03636	4.036	.41542E+00	.10000E+01	-2.795380	94.01	32062.72	0.207714
0.03636	4.131	.40320E+00	.10000E+01	-2.811049	94.47	32823.74	0.201603
0.03636	4.227	.39145E+00	.10000E+01	-2.825916	94.93	33584.75	0.195729
0.03636	4.323	.38020E+00	.10000E+01	-2.840121	95.37	34345.77	0.190102
0.03636	4.419	.36938E+00	.10000E+01	-2.853571	95.82	35106.79	0.184694
0.03636	4.514	.35902E+00	.10000E+01	-2.866457	96.25	35867.80	0.179514
0.03636	4.610	.34908E+00	.10000E+01	-2.878731	96.68	36628.82	0.174545
0.03636	4.706	.33954E+00	.10000E+01	-2.890428	97.09	37389.83	0.169774
0.03636	4.802	.33043E+00	.10000E+01	-2.901717	97.51	38150.85	0.165219
0.03636	4.898	.32165E+00	.10000E+01	-2.912356	97.91	38911.86	0.160827
0.03636	4.993	.31324E+00	.10000E+01	-2.922489	98.31	39672.88	0.156625
0.03636	5.089	.30513E+00	.10000E+01	-2.932023	98.70	40433.89	0.152569
0.03636	5.185	.29737E+00	.10000E+01	-2.941154	99.09	41194.91	0.148689
0.03636	5.281	.28989E+00	.10000E+01	-2.949830	99.47	41955.93	0.144946
0.03636	5.376	.28270E+00	.10000E+01	-2.958015	99.84	42716.94	0.141354
0.03636	5.472	.27584E+00	.10000E+01	-2.966000	100.21	43477.96	0.137920
0.03636	5.568	.26920E+00	.10000E+01	-2.973444	100.57	44238.97	0.134600
0.03636	5.664	.26282E+00	.10000E+01	-2.980516	100.93	44999.99	0.131413

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VERSION DATE      = : 05/12/83
DATA FILE         = : SEAWAT.DAT
GRAPH ? (Y/N)     = : N
NUMBER OF POINTS  =   60
DISTANCE          =    45.00
STARTING POINT    =     0.10
TRANSMITTER HEIGHT=     0.00
RECEIVER HEIGHT   =     0.00
FREQUENCY         =    25.40
NUMBER OF LAYERS  =   0
NUMBER OF RUNS    =   6
 REL. PERM. (BOTTOM)=  78.9900
      COND. (BOTTOM)=   2.1500
   NORMALIZED SURFACE IMPEDENCE = 0.0185715 + 0.0176208 i
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NUMERICAL DISTANCE		ELECTRIC FIELD					
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	LOSS (DB)	DISTANCE (METERS)	MAGNITUDE OF F(W)
0.05252	0.017	.19729E+01	.10000E+01	-0.234011	30.36	100.00	0.986493
0.05252	0.150	.18428E+01	.10000E+01	-0.678881	49.65	861.02	0.921450
0.05252	0.283	.17311E+01	.10000E+01	-0.923924	55.69	1622.03	0.865600
0.05252	0.415	.16294E+01	.10000E+01	-1.110934	59.56	2383.05	0.814714
0.05252	0.548	.15355E+01	.10000E+01	-1.266093	62.48	3144.07	0.767760
0.05252	0.681	.14484E+01	.10000E+01	-1.400138	64.87	3905.09	0.724202
0.05252	0.813	.13673E+01	.10000E+01	-1.518731	66.92	4666.10	0.683674
0.05252	0.946	.12917E+01	.10000E+01	-1.625325	68.73	5427.12	0.645882
0.05252	1.079	.12211E+01	.10000E+01	-1.722225	70.35	6188.14	0.610585
0.05252	1.211	.11551E+01	.10000E+01	-1.811003	71.84	6949.15	0.577591
0.05252	1.344	.10934E+01	.10000E+01	-1.892813	73.22	7710.17	0.546725
0.05252	1.477	.10356E+01	.10000E+01	-1.968396	74.51	8471.19	0.517822
0.05252	1.609	.98145E+00	.10000E+01	-2.039090	75.73	9232.20	0.490742
0.05252	1.742	.93069E+00	.10000E+01	-2.104812	76.88	9993.22	0.465359
0.05252	1.875	.88308E+00	.10000E+01	-2.166203	77.97	10754.24	0.441557
0.05252	2.007	.83842E+00	.10000E+01	-2.223705	79.01	11515.25	0.419225
0.05252	2.140	.79650E+00	.10000E+01	-2.277669	80.02	12276.27	0.398263
0.05252	2.273	.75715E+00	.10000E+01	-2.328323	80.98	13037.29	0.378587
0.05252	2.405	.72019E+00	.10000E+01	-2.375941	81.91	13798.30	0.360107
0.05252	2.538	.68546E+00	.10000E+01	-2.420643	82.80	14559.32	0.342742
0.05252	2.671	.65282E+00	.10000E+01	-2.462737	83.67	15320.34	0.326423
0.05252	2.803	.62215E+00	.10000E+01	-2.502423	84.51	16081.35	0.311086
0.05252	2.936	.59330E+00	.10000E+01	-2.539747	85.32	16842.37	0.296662
0.05252	3.069	.56617E+00	.10000E+01	-2.574830	86.11	17603.39	0.283093
0.05252	3.201	.54064E+00	.10000E+01	-2.607879	86.88	18364.41	0.270328
0.05252	3.334	.51661E+00	.10000E+01	-2.638966	87.63	19125.42	0.258313
0.05252	3.467	.49400E+00	.10000E+01	-2.668314	88.35	19886.44	0.247006
0.05252	3.599	.47270E+00	.10000E+01	-2.695873	89.06	20647.46	0.236358
0.05252	3.732	.45263E+00	.10000E+01	-2.721706	89.75	21408.48	0.226324
0.05252	3.865	.43372E+00	.10000E+01	-2.746018	90.43	22169.49	0.216869

NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(U)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
0.05252	4.263	.38327E+00	.10000E+01	-2.810527	92.35	24452.55	0.191639
0.05252	4.395	.34831E+00	.10000E+01	-2.829325	92.97	25213.56	0.184163
0.05252	4.528	.35419E+00	.10000E+01	-2.846963	93.56	25974.58	0.177103
0.05252	4.661	.34087E+00	.10000E+01	-2.863475	94.15	26735.60	0.170442
0.05252	4.793	.32831E+00	.10000E+01	-2.879077	94.72	27496.62	0.164162
0.05252	4.926	.31641E+00	.10000E+01	-2.893588	95.28	28257.63	0.158210
0.05252	5.059	.30519E+00	.10000E+01	-2.907182	95.82	29018.65	0.152599
0.05252	5.191	.29455E+00	.10000E+01	-2.919622	96.35	29779.67	0.147279
0.05252	5.324	.28450E+00	.10000E+01	-2.931341	96.87	30540.69	0.142254
0.05252	5.457	.27495E+00	.10000E+01	-2.942410	97.38	31301.71	0.137477
0.05252	5.589	.26597E+00	.10000E+01	-2.952705	97.88	32062.72	0.132989
0.05252	5.722	.25744E+00	.10000E+01	-2.962282	98.37	32823.74	0.128723
0.05252	5.855	.24933E+00	.10000E+01	-2.970997	98.84	33584.75	0.124669
0.05252	5.987	.24167E+00	.10000E+01	-2.979039	99.31	34345.77	0.120841
0.05252	6.120	.23438E+00	.10000E+01	-2.986850	99.77	35106.79	0.117193
0.05252	6.253	.22740E+00	.10000E+01	-2.993840	100.22	35867.80	0.113702
0.05252	6.385	.22088E+00	.10000E+01	-3.000570	100.65	36628.82	0.110442
0.05252	6.518	.21471E+00	.10000E+01	-3.006514	101.08	37389.83	0.107358
0.05252	6.651	.20866E+00	.10000E+01	-3.012117	101.50	38150.85	0.104336
0.05252	6.783	.20308E+00	.10000E+01	-3.017117	101.91	38911.86	0.101542
0.05252	6.916	.19768E+00	.10000E+01	-3.022482	102.31	39672.88	0.098843
0.05252	7.049	.19241E+00	.10000E+01	-3.026674	102.71	40433.89	0.096207
0.05252	7.181	.18759E+00	.10000E+01	-3.030718	103.09	41194.91	0.093799
0.05252	7.314	.18295E+00	.10000E+01	-3.034312	103.47	41955.93	0.091479
0.05252	7.447	.17861E+00	.10000E+01	-3.037822	103.83	42716.94	0.089309
0.05252	7.579	.17443E+00	.10000E+01	-3.041681	104.19	43477.96	0.087220
0.05252	7.712	.17025E+00	.10000E+01	-3.044654	104.55	44238.97	0.085129
0.05252	7.845	.16637E+00	.10000E+01	-3.047436	104.90	44999.99	0.083186

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VERSION DATE      = : 05/12/83
DATA FILE         = : SEAMAT.DAT
GRAPH ? (Y/N)     = : N
NUMBER OF POINTS  =   60
DISTANCE          =    45.00
STARTING POINT    =     0.10
TRANSMITTER HEIGHT=     0.00
RECEIVER HEIGHT   =     0.00
FREQUENCY         =    25.40
NUMBER OF LAYERS  =   0
NUMBER OF RUNS    =   6
  REL. PERM. (BOTTOM)=  80.6300
       COND. (BOTTOM)=   1.7400
         NORMALIZED SURFACE IMPEDENCE = 0.0207689 + 0.0194377 i
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NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(W)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
0.06619	0.022	.19646E+01	.10000E+01	-0.259823	30.39	100.00	0.982345
0.06619	0.185	.18029E+01	.10000E+01	-0.751309	49.84	861.02	0.901508
0.06619	0.349	.16680E+01	.10000E+01	-1.020416	56.01	1622.03	0.834025
0.06619	0.513	.15474E+01	.10000E+01	-1.224311	60.01	2383.05	0.773759
0.06619	0.677	.14382E+01	.10000E+01	-1.392366	63.05	3144.07	0.719158
0.06619	0.840	.13387E+01	.10000E+01	-1.536549	65.56	3905.09	0.669379
0.06619	1.004	.12476E+01	.10000E+01	-1.663235	67.72	4666.10	0.623809
0.06619	1.168	.11639E+01	.10000E+01	-1.776266	69.63	5427.12	0.581996
0.06619	1.332	.10871E+01	.10000E+01	-1.878170	71.36	6188.14	0.543566
0.06619	1.496	.10163E+01	.10000E+01	-1.970774	72.96	6949.15	0.508191
0.06619	1.659	.95112E+00	.10000E+01	-2.055454	74.43	7710.17	0.475583
0.06619	1.823	.89098E+00	.10000E+01	-2.133138	75.82	8471.19	0.445513
0.06619	1.987	.83546E+00	.10000E+01	-2.204679	77.13	9232.20	0.417753
0.06619	2.151	.78417E+00	.10000E+01	-2.270757	78.36	9993.22	0.392165
0.06619	2.315	.73675E+00	.10000E+01	-2.331863	79.54	10754.24	0.368397
0.06619	2.478	.69290E+00	.10000E+01	-2.388408	80.67	11515.25	0.346470
0.06619	2.642	.65232E+00	.10000E+01	-2.440837	81.75	12276.27	0.326177
0.06619	2.806	.61473E+00	.10000E+01	-2.489526	82.79	13037.29	0.307383
0.06619	2.970	.57991E+00	.10000E+01	-2.534686	83.79	13798.30	0.289972
0.06619	3.134	.54764E+00	.10000E+01	-2.576516	84.75	14559.32	0.273835
0.06619	3.297	.51771E+00	.10000E+01	-2.615356	85.68	15320.34	0.258871
0.06619	3.461	.48994E+00	.10000E+01	-2.651461	86.58	16081.35	0.244982
0.06619	3.625	.46415E+00	.10000E+01	-2.684907	87.45	16842.37	0.232089
0.06619	3.789	.44022E+00	.10000E+01	-2.715809	88.30	17603.39	0.220121
0.06619	3.953	.41796E+00	.10000E+01	-2.744452	89.11	18364.41	0.208993
0.06619	4.116	.39727E+00	.10000E+01	-2.771069	89.91	19125.42	0.198648
0.06619	4.280	.37802E+00	.10000E+01	-2.795623	90.68	19886.44	0.189020
0.06619	4.444	.36012E+00	.10000E+01	-2.818202	91.43	20647.46	0.180069
0.06619	4.608	.34343E+00	.10000E+01	-2.839073	92.15	21408.48	0.171722
0.06619	4.772	.32787E+00	.10000E+01	-2.858430	92.86	22169.49	0.163943

NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(W)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
0.06619	4.935	.31338E+00	.10000E+01	-2.876225	93.54	22930.51	0.156696
0.06619	5.099	.29986E+00	.10000E+01	-2.892456	94.21	23691.53	0.149939
0.06619	5.263	.28724E+00	.10000E+01	-2.907479	94.86	24452.55	0.143630
0.06619	5.427	.27542E+00	.10000E+01	-2.921366	95.49	25213.56	0.137719
0.06619	5.590	.26438E+00	.10000E+01	-2.934005	96.10	25974.58	0.132199
0.06619	5.754	.25404E+00	.10000E+01	-2.945663	96.70	26735.60	0.127025
0.06619	5.918	.24443E+00	.10000E+01	-2.956116	97.28	27496.62	0.122222
0.06619	6.082	.23533E+00	.10000E+01	-2.965612	97.85	28257.63	0.117673
0.06619	6.246	.22681E+00	.10000E+01	-2.974833	98.40	29018.65	0.113411
0.06619	6.409	.21885E+00	.10000E+01	-2.983126	98.93	29779.67	0.109431
0.06619	6.573	.21130E+00	.10000E+01	-2.990034	99.46	30540.69	0.105657
0.06619	6.737	.20407E+00	.10000E+01	-2.996462	99.97	31301.71	0.102042
0.06619	6.901	.19762E+00	.10000E+01	-3.002954	100.46	32062.72	0.098818
0.06619	7.065	.19137E+00	.10000E+01	-3.008619	100.94	32823.74	0.095692
0.06619	7.228	.18533E+00	.10000E+01	-3.013410	101.42	33584.75	0.092670
0.06619	7.392	.18000E+00	.10000E+01	-3.018221	101.87	34345.77	0.090006
0.06619	7.556	.17450E+00	.10000E+01	-3.022796	102.33	35106.79	0.087256
0.06619	7.720	.17984E+00	.10000E+01	-3.025921	102.75	35867.80	0.084926
0.06619	7.884	.16497E+00	.10000E+01	-3.030644	103.19	36628.82	0.082490
0.06619	8.047	.16023E+00	.10000E+01	-3.033257	103.62	37389.83	0.080119
0.06619	8.211	.15603E+00	.10000E+01	-3.035455	104.02	38150.85	0.078020
0.06619	8.375	.15205E+00	.10000E+01	-3.038393	104.42	38911.86	0.076029
0.06619	8.539	.14824E+00	.10000E+01	-3.042380	104.81	39672.88	0.074125
0.06619	8.703	.14446E+00	.10000E+01	-3.042297	105.20	40433.89	0.072233
0.06619	8.866	.14071E+00	.10000E+01	-3.046288	105.59	41194.91	0.070359
0.06619	9.030	.13766E+00	.10000E+01	-3.045034	105.94	41955.93	0.068834
0.06619	9.194	.13567E+00	.10000E+01	-3.054579	106.22	42716.94	0.067841
0.06619	9.358	.13165E+00	.10000E+01	-3.054623	106.63	43477.96	0.065828
0.06619	9.522	.12889E+00	.10000E+01	-3.048227	106.97	44238.97	0.064449
0.06619	9.685	.12378E+00	.10000E+01	-3.043897	107.47	44999.99	0.061895

VERSION DATE = : 05/12/83

DATA FILE = : SEAWAT.DAT
GRAPH ? (Y/N) = : N
NUMBER OF POINTS = 60
DISTANCE = 45.00
STARTING POINT = 0.10
TRANSMITTER HEIGHT= 0.00
RECEIVER HEIGHT = 0.00
FREQUENCY = 25.40
NUMBER OF LAYERS = 0
NUMBER OF RUNS = 6
REL. PERM. (BOTTOM)= 83.9000
COND. (BOTTOM)= 0.9100
NORMALIZED SURFACE IMPEDENCE = 0.0294807 + 0.0258493 i

NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(N)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
0.13107	0.041	.19198E+01	.10000E+01	-0.356199	30.39	100.00	0.960093
0.13107	0.352	.16139E+01	.10000E+01	-1.014207	50.80	861.02	0.807105
0.13107	0.663	.13890E+01	.10000E+01	-1.360753	57.60	1622.03	0.694661
0.13107	0.974	.12063E+01	.10000E+01	-1.614448	62.17	2383.05	0.603264
0.13107	1.286	.10542E+01	.10000E+01	-1.816074	65.75	3144.07	0.527185
0.13107	1.597	.92603E+00	.10000E+01	-1.982547	68.76	3905.09	0.463107
0.13107	1.908	.81735E+00	.10000E+01	-2.122899	71.39	4666.10	0.408756
0.13107	2.219	.72463E+00	.10000E+01	-2.242737	73.75	5427.12	0.362388
0.13107	2.530	.64526E+00	.10000E+01	-2.345798	75.89	6188.14	0.322694
0.13107	2.842	.57701E+00	.10000E+01	-2.434853	77.87	6949.15	0.288561
0.13107	3.153	.51820E+00	.10000E+01	-2.511942	79.71	7710.17	0.259132
0.13107	3.464	.46732E+00	.10000E+01	-2.578757	81.42	8471.19	0.233707
0.13107	3.775	.42324E+00	.10000E+01	-2.636610	83.03	9232.20	0.211663
0.13107	4.086	.38489E+00	.10000E+01	-2.686694	84.54	9993.22	0.192484
0.13107	4.397	.35148E+00	.10000E+01	-2.729929	85.97	10754.24	0.175777
0.13107	4.709	.32230E+00	.10000E+01	-2.767236	87.32	11515.25	0.161183
0.13107	5.020	.29664E+00	.10000E+01	-2.799403	88.59	12276.27	0.148352
0.13107	5.331	.27418E+00	.10000E+01	-2.826879	89.80	13037.29	0.137120
0.13107	5.642	.25428E+00	.10000E+01	-2.850539	90.95	13798.30	0.127165
0.13107	5.953	.23682E+00	.10000E+01	-2.870760	92.03	14559.32	0.118435
0.13107	6.265	.22116E+00	.10000E+01	-2.887905	93.07	15320.34	0.110600
0.13107	6.576	.20721E+00	.10000E+01	-2.903084	94.06	16081.35	0.103625
0.13107	6.887	.19494E+00	.10000E+01	-2.915579	94.99	16842.37	0.097491
0.13107	7.198	.18393E+00	.10000E+01	-2.927058	95.88	17603.39	0.091983
0.13107	7.509	.17376E+00	.10000E+01	-2.936093	96.74	18364.41	0.086898
0.13107	7.820	.16483E+00	.10000E+01	-2.943417	97.55	19125.42	0.082431
0.13107	8.132	.15687E+00	.10000E+01	-2.948279	98.32	19886.44	0.078449
0.13107	8.443	.14934E+00	.10000E+01	-2.956802	99.07	20647.46	0.074685
0.13107	8.754	.14210E+00	.10000E+01	-2.962638	99.82	21408.48	0.071066
0.13107	9.065	.13598E+00	.10000E+01	-2.967076	100.50	22169.49	0.068003

NUMERICAL DISTANCE PHASE (RAD)	DISTANCE MAGNTD	ELECTRIC FIELD MAGNTD	FACTOR	PHASE	LOSS (DB)	DISTANCE (METERS)	MAGNITUDE OF F(N)
0.13107	9.376	.13045E+00	.10000E+01	-2.970039	101.16	22930.51	0.065240
0.13107	9.688	.12657E+00	.10000E+01	-2.966332	101.70	23691.53	0.063300
0.13107	9.999	.11889E+00	.10000E+01	-2.998612	102.52	24452.55	0.059456
0.13107	10.310	.11617E+00	.10000E+01	-2.980060	102.99	25213.56	0.058098
0.13107	10.621	.11189E+00	.10000E+01	-2.982545	103.57	25974.58	0.055959
0.13107	10.932	.10804E+00	.10000E+01	-2.983891	104.13	26735.60	0.054029
0.13107	11.243	.10444E+00	.10000E+01	-2.985123	104.67	27496.62	0.052231
0.13107	11.555	.10108E+00	.10000E+01	-2.986232	105.19	28257.63	0.050551
0.13107	11.866	.97937E-01	.10000E+01	-2.987291	105.69	29018.65	0.048979
0.13107	12.177	.94906E-01	.10000E+01	-2.988870	106.19	29779.67	0.047463
0.13107	12.488	.92142E-01	.10000E+01	-2.989687	106.67	30540.69	0.046080
0.13107	12.799	.89537E-01	.10000E+01	-2.990430	107.13	31301.71	0.044778
0.13107	13.111	.87078E-01	.10000E+01	-2.991164	107.58	32062.72	0.043547
0.13107	13.422	.84751E-01	.10000E+01	-2.991832	108.02	32823.74	0.042384
0.13107	13.733	.82547E-01	.10000E+01	-2.992460	108.45	33584.75	0.041282
0.13107	14.044	.80455E-01	.10000E+01	-2.993051	108.86	34345.77	0.040236
0.13107	14.355	.78469E-01	.10000E+01	-2.993608	109.27	35106.79	0.039242
0.13107	14.666	.76579E-01	.10000E+01	-2.994133	109.67	35867.80	0.038297
0.13107	14.978	.74779E-01	.10000E+01	-2.994630	110.06	36628.82	0.037397
0.13107	15.289	.73062E-01	.10000E+01	-2.995100	110.44	37389.83	0.036538
0.13107	15.600	.71423E-01	.10000E+01	-2.995545	110.81	38150.85	0.035719
0.13107	15.911	.69806E-01	.10000E+01	-2.996372	111.18	38911.86	0.034910
0.13107	16.222	.68312E-01	.10000E+01	-2.996745	111.54	39672.88	0.034163
0.13107	16.534	.66881E-01	.10000E+01	-2.997101	111.89	40433.89	0.033447
0.13107	16.845	.65509E-01	.10000E+01	-2.997441	112.23	41194.91	0.032761
0.13107	17.156	.64193E-01	.10000E+01	-2.997766	112.56	41955.93	0.032103
0.13107	17.467	.62928E-01	.10000E+01	-2.998078	112.89	42716.94	0.031470
0.13107	17.778	.61713E-01	.10000E+01	-2.998376	113.22	43477.96	0.030863
0.13107	18.089	.60544E-01	.10000E+01	-2.998662	113.53	44238.97	0.030278
0.13107	18.401	.59419E-01	.10000E+01	-2.998937	113.84	44999.99	0.029715

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VERSION DATE      = : 05/12/83
DATA FILE         = : SEAMAT.DAT
GRAPH ? (Y/N)     = : N
NUMBER OF POINTS  =   60
DISTANCE          =    45.00
STARTING POINT    =     0.10
TRANSMITTER HEIGHT=     0.00
RECEIVER HEIGHT   =     0.00
FREQUENCY         =    25.40
NUMBER OF LAYERS  =   0
NUMBER OF RUNS    =   6
  REL. PERM. (BOTTOM)=  85.5400
       COND. (BOTTOM)=   0.5000
         NORMALIZED SURFACE IMPEDENCE = 0.0411859 + 0.0323270 i
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NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(N)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
0.23986	0.073	.18321E+01	.10000E+01	-0.468881	31.00	100.00	0.916636
0.23986	0.628	.13237E+01	.10000E+01	-1.295057	52.52	861.02	0.662298
0.23986	1.183	.10186E+01	.10000E+01	-1.698697	60.30	1622.03	0.509643
0.23986	1.738	.80497E+00	.10000E+01	-1.973715	65.68	2383.05	0.402743
0.23986	2.293	.64888E+00	.10000E+01	-2.176128	69.96	3144.07	0.324650
0.23986	2.847	.53211E+00	.10000E+01	-2.329874	73.57	3905.09	0.266226
0.23986	3.402	.44324E+00	.10000E+01	-2.448316	76.70	4666.10	0.221766
0.23986	3.957	.37465E+00	.10000E+01	-2.540179	79.48	5427.12	0.187448
0.23986	4.512	.32106E+00	.10000E+01	-2.611403	81.96	6188.14	0.160633
0.23986	5.067	.27869E+00	.10000E+01	-2.666705	84.19	6949.15	0.139433
0.23986	5.622	.24483E+00	.10000E+01	-2.709783	86.22	7710.17	0.122494
0.23986	6.177	.21734E+00	.10000E+01	-2.743327	88.07	8471.19	0.108740
0.23986	6.732	.19484E+00	.10000E+01	-2.769622	89.77	9232.20	0.097481
0.23986	7.287	.17635E+00	.10000E+01	-2.788945	91.32	9993.22	0.088233
0.23986	7.842	.16066E+00	.10000E+01	-2.807039	92.77	10754.24	0.080380
0.23986	8.396	.14777E+00	.10000E+01	-2.819499	94.09	11515.25	0.073932
0.23986	8.951	.13666E+00	.10000E+01	-2.827538	95.33	12276.27	0.068374
0.23986	9.506	.12672E+00	.10000E+01	-2.833824	96.50	13037.29	0.063403
0.23986	10.061	.11858E+00	.10000E+01	-2.846848	97.57	13798.30	0.059328
0.23986	10.616	.11110E+00	.10000E+01	-2.851665	98.61	14559.32	0.055586
0.23986	11.171	.10453E+00	.10000E+01	-2.855749	99.58	15320.34	0.052297
0.23986	11.726	.98649E-01	.10000E+01	-2.860408	100.50	16081.35	0.049357
0.23986	12.281	.93460E-01	.10000E+01	-2.863211	101.37	16842.37	0.046760
0.23986	12.836	.88795E-01	.10000E+01	-2.865685	102.20	17603.39	0.044426
0.23986	13.391	.84579E-01	.10000E+01	-2.867884	102.99	18364.41	0.042317
0.23986	13.945	.80748E-01	.10000E+01	-2.869850	103.75	19125.42	0.040400
0.23986	14.500	.77253E-01	.10000E+01	-2.871617	104.47	19886.44	0.038651
0.23986	15.055	.74004E-01	.10000E+01	-2.874040	105.17	20647.46	0.037026
0.23986	15.610	.71045E-01	.10000E+01	-2.875382	105.84	21408.48	0.035556
0.23986	16.165	.68352E-01	.10000E+01	-2.876614	106.48	22169.49	0.034198

NUMERICAL DISTANCE PHASE (RAD)	NUMERICAL DISTANCE MAGNTD	ELECTRIC FIELD MAGNTD	ELECTRIC FIELD FACTOR	PHASE	LOSS (DB)	DISTANCE (METERS)	MAGNITUDE OF F(N)
0.23986	16.720	.65840E-01	.10000E+01	-2.877746	107.10	22930.51	0.032941
0.23986	17.275	.63506E-01	.10000E+01	-2.878792	107.69	23691.53	0.031774
0.23986	17.830	.61333E-01	.10000E+01	-2.879761	108.27	24452.55	0.030686
0.23986	18.385	.59304E-01	.10000E+01	-2.880660	108.83	25213.56	0.029671
0.23986	18.940	.57406E-01	.10000E+01	-2.881496	109.37	25974.58	0.028722
0.23986	19.494	.55626E-01	.10000E+01	-2.882277	109.89	26735.60	0.027831
0.23986	20.049	.53953E-01	.10000E+01	-2.883007	110.40	27496.62	0.026994
0.23986	20.604	.52378E-01	.10000E+01	-2.883691	110.90	28257.63	0.026206
0.23986	21.159	.50893E-01	.10000E+01	-2.884332	111.38	29018.65	0.025463
0.23986	21.714	.49490E-01	.10000E+01	-2.884936	111.85	29779.67	0.024761
0.23986	22.269	.48163E-01	.10000E+01	-2.885505	112.30	30540.69	0.024097
0.23986	22.824	.46905E-01	.10000E+01	-2.886042	112.74	31301.71	0.023467
0.23986	23.379	.45711E-01	.10000E+01	-2.886549	113.18	32062.72	0.022870
0.23986	23.934	.44576E-01	.10000E+01	-2.887029	113.60	32823.74	0.022303
0.23986	24.489	.43497E-01	.10000E+01	-2.887484	114.01	33584.75	0.021763
0.23986	25.043	.42469E-01	.10000E+01	-2.887917	114.41	34345.77	0.021248
0.23986	25.598	.41465E-01	.10000E+01	-2.888804	114.81	35106.79	0.020746
0.23986	26.153	.40531E-01	.10000E+01	-2.889166	115.20	35867.80	0.020279
0.23986	26.708	.39638E-01	.10000E+01	-2.889512	115.57	36628.82	0.019832
0.23986	27.263	.38783E-01	.10000E+01	-2.889843	115.94	37389.83	0.019404
0.23986	27.818	.37965E-01	.10000E+01	-2.890159	116.30	38150.85	0.018995
0.23986	28.373	.37180E-01	.10000E+01	-2.890463	116.65	38911.86	0.018602
0.23986	28.928	.36427E-01	.10000E+01	-2.890753	117.00	39672.88	0.018225
0.23986	29.483	.35704E-01	.10000E+01	-2.891033	117.34	40433.89	0.017864
0.23986	30.038	.35010E-01	.10000E+01	-2.891300	117.67	41194.91	0.017516
0.23986	30.592	.34341E-01	.10000E+01	-2.891558	118.00	41955.93	0.017182
0.23986	31.147	.33698E-01	.10000E+01	-2.891806	118.32	42716.94	0.016860
0.23986	31.702	.33079E-01	.10000E+01	-2.892045	118.63	43477.96	0.016550
0.23986	32.257	.32482E-01	.10000E+01	-2.892274	118.94	44238.97	0.016251
0.23986	32.812	.31906E-01	.10000E+01	-2.892496	119.24	44999.99	0.015963

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VERSION DATE      = : 05/12/83
DATA FILE         = : SEAWAT.DAT
GRAPH ? (Y/N)     = : N
NUMBER OF POINTS  =   60
DISTANCE          =    45.00
STARTING POINT    =     0.10
TRANSMITTER HEIGHT=     0.00
RECEIVER HEIGHT   =     0.00
FREQUENCY         =    25.40
NUMBER OF LAYERS  =    0
NUMBER OF RUNS    =    6
  REL. PERM. (BOTTOM)=  87.1700
       COND. (BOTTOM)=   0.0830
         NORMALIZED SURFACE IMPEDENCE = 0.0929244 + 0.0281150 i
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NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(N)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
0.98319	0.251	.12424E+01	.10000E+01	-0.697568	34.37	100.00	0.626080
0.98319	2.159	.44622E+00	.10000E+01	-1.546353	61.97	861.02	0.224868
0.98319	4.067	.26009E+00	.10000E+01	-1.793088	72.16	1622.03	0.131072
0.98319	5.974	.17910E+00	.10000E+01	-1.909074	78.74	2383.05	0.090256
0.98319	7.882	.13516E+00	.10000E+01	-1.973318	83.59	3144.07	0.068112
0.98319	9.790	.10796E+00	.10000E+01	-2.037520	87.42	3905.09	0.054407
0.98319	11.698	.89781E-01	.10000E+01	-2.040665	90.57	4666.10	0.045245
0.98319	13.606	.76769E-01	.10000E+01	-2.058784	93.25	5427.12	0.038688
0.98319	15.514	.67006E-01	.10000E+01	-2.073067	95.57	6188.14	0.033767
0.98319	17.422	.59449E-01	.10000E+01	-2.083560	97.61	6949.15	0.029959
0.98319	19.330	.53473E-01	.10000E+01	-2.092722	99.44	7710.17	0.026947
0.98319	21.238	.48497E-01	.10000E+01	-2.099606	101.10	8471.19	0.024440
0.98319	23.146	.44367E-01	.10000E+01	-2.105279	102.62	9232.20	0.022358
0.98319	25.053	.40884E-01	.10000E+01	-2.110033	104.02	9993.22	0.020603
0.98319	26.961	.37908E-01	.10000E+01	-2.114076	105.31	10754.24	0.019104
0.98319	28.869	.35336E-01	.10000E+01	-2.117554	106.52	11515.25	0.017807
0.98319	30.777	.33090E-01	.10000E+01	-2.120577	107.64	12276.27	0.016675
0.98319	32.685	.31112E-01	.10000E+01	-2.123230	108.70	13037.29	0.015679
0.98319	34.593	.29357E-01	.10000E+01	-2.125576	109.70	13798.30	0.014795
0.98319	36.501	.27790E-01	.10000E+01	-2.127664	110.64	14559.32	0.014005
0.98319	38.409	.26381E-01	.10000E+01	-2.129537	111.54	15320.34	0.013295
0.98319	40.317	.25108E-01	.10000E+01	-2.131225	112.39	16081.35	0.012653
0.98319	42.225	.23953E-01	.10000E+01	-2.132755	113.20	16842.37	0.012071
0.98319	44.132	.22899E-01	.10000E+01	-2.134144	113.97	17603.39	0.011540
0.98319	46.040	.21933E-01	.10000E+01	-2.135417	114.71	18364.41	0.011053
0.98319	47.948	.21046E-01	.10000E+01	-2.136586	115.43	19125.42	0.010604
0.98319	49.856	.20228E-01	.10000E+01	-2.137660	116.11	19886.44	0.010194
0.98319	51.764	.19471E-01	.10000E+01	-2.138649	116.77	20647.46	0.009812
0.98319	53.672	.18768E-01	.10000E+01	-2.139568	117.40	21408.48	0.009458
0.98319	55.580	.18115E-01	.10000E+01	-2.140425	118.01	22169.49	0.009129

NUMERICAL PHASE (RAD)	DISTANCE MAGNTD	ELECTRIC FIELD MAGNTD	FACTOR	PHASE	LOSS (DB)	DISTANCE (METERS)	MAGNITUDE OF F(U)
0.98319	57.488	.17505E-01	.10000E+01	-2.141222	118.60	22930.51	0.008822
0.98319	59.396	.16935E-01	.10000E+01	-2.141963	119.17	23691.53	0.008535
0.98319	61.304	.16401E-01	.10000E+01	-2.142659	119.73	24452.55	0.008265
0.98319	63.212	.15900E-01	.10000E+01	-2.143317	120.26	25213.56	0.008013
0.98319	65.119	.15433E-01	.10000E+01	-2.143940	120.78	25974.58	0.007778
0.98319	67.027	.14989E-01	.10000E+01	-2.145271	121.28	26735.60	0.007553
0.98319	68.935	.14569E-01	.10000E+01	-2.145777	121.77	27496.62	0.007342
0.98319	70.843	.14172E-01	.10000E+01	-2.146251	122.25	28257.63	0.007142
0.98319	72.751	.13796E-01	.10000E+01	-2.146700	122.72	29018.65	0.006952
0.98319	74.659	.13439E-01	.10000E+01	-2.147130	123.17	29779.67	0.006773
0.98319	76.567	.13101E-01	.10000E+01	-2.147539	123.61	30540.69	0.006602
0.98319	78.475	.12779E-01	.10000E+01	-2.147924	124.04	31301.71	0.006440
0.98319	80.383	.12472E-01	.10000E+01	-2.148297	124.46	32062.72	0.006285
0.98319	82.291	.12180E-01	.10000E+01	-2.148647	124.87	32823.74	0.006138
0.98319	84.198	.11901E-01	.10000E+01	-2.148984	125.27	33584.75	0.005998
0.98319	86.106	.11635E-01	.10000E+01	-2.149310	125.66	34345.77	0.005863
0.98319	88.014	.11380E-01	.10000E+01	-2.149612	126.04	35106.79	0.005735
0.98319	89.922	.11137E-01	.10000E+01	-2.149910	126.42	35867.80	0.005612
0.98319	91.830	.10903E-01	.10000E+01	-2.150196	126.78	36628.82	0.005495
0.98319	93.738	.10679E-01	.10000E+01	-2.150468	127.14	37389.83	0.005382
0.98319	95.646	.10464E-01	.10000E+01	-2.150731	127.49	38150.85	0.005274
0.98319	97.554	.10258E-01	.10000E+01	-2.150980	127.84	38911.86	0.005169
0.98319	99.462	.10060E-01	.10000E+01	-2.151216	128.18	39672.88	0.005069
0.98319	101.370	.98687E-02	.10000E+01	-2.151449	128.51	40433.89	0.004973
0.98319	103.277	.96849E-02	.10000E+01	-2.151679	128.83	41194.91	0.004881
0.98319	105.185	.95078E-02	.10000E+01	-2.151892	129.15	41955.93	0.004791
0.98319	107.093	.93371E-02	.10000E+01	-2.152095	129.47	42716.94	0.004705
0.98319	109.001	.91724E-02	.10000E+01	-2.152303	129.77	43477.96	0.004622
0.98319	110.909	.90134E-02	.10000E+01	-2.152489	130.08	44238.97	0.004542
0.98319	112.817	.88598E-02	.10000E+01	-2.152678	130.37	44999.99	0.004465

```
VERSION DATE      = : 05/12/83
DATA FILE         = : seaut.dat
GRAPH ? (Y/N)     = : n
NUMBER OF POINTS  =   60
DISTANCE          =    45.00
STARTING POINT    =     0.10
TRANSMITTER HEIGHT=     0.00
RECEIVER HEIGHT   =     0.00
FREQUENCY         =    25.40
NUMBER OF LAYERS  =   0
NUMBER OF RUNS    =   6
  REL. PERM. (BOTTOM)=  72.5100
       COND. (BOTTOM)=   3.9400
         NORMALIZED SURFACE IMPEDENCE = 0.0135544 + 0.0132018 i
```

NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(N)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
-0.02636	0.010	.19873E+01	.10000E+01	-0.173120	30.29	100.00	0.993659
-0.02636	0.082	.19182E+01	.10000E+01	-0.504949	49.30	861.02	0.959125
-0.02636	0.154	.18553E+01	.10000E+01	-0.690045	55.09	1622.03	0.927683
-0.02636	0.227	.17957E+01	.10000E+01	-0.833003	58.72	2383.05	0.897865
-0.02636	0.299	.17387E+01	.10000E+01	-0.952983	61.40	3144.07	0.869358
-0.02636	0.372	.16840E+01	.10000E+01	-1.057866	63.56	3905.09	0.842017
-0.02636	0.444	.16315E+01	.10000E+01	-1.151809	65.39	4666.10	0.815736
-0.02636	0.517	.15809E+01	.10000E+01	-1.237322	66.97	5427.12	0.790443
-0.02636	0.589	.15322E+01	.10000E+01	-1.316054	68.38	6188.14	0.766084
-0.02636	0.662	.14852E+01	.10000E+01	-1.389170	69.66	6949.15	0.742611
-0.02636	0.734	.14400E+01	.10000E+01	-1.457510	70.83	7710.17	0.719982
-0.02636	0.807	.13963E+01	.10000E+01	-1.521738	71.92	8471.19	0.698157
-0.02636	0.879	.13542E+01	.10000E+01	-1.582354	72.93	9232.20	0.677100
-0.02636	0.952	.13136E+01	.10000E+01	-1.639763	73.88	9993.22	0.656782
-0.02636	1.024	.12743E+01	.10000E+01	-1.694320	74.78	10754.24	0.637169
-0.02636	1.097	.12365E+01	.10000E+01	-1.746264	75.64	11515.25	0.618236
-0.02636	1.169	.11999E+01	.10000E+01	-1.795842	76.46	12276.27	0.599957
-0.02636	1.241	.11646E+01	.10000E+01	-1.843225	77.24	13037.29	0.582305
-0.02636	1.314	.11305E+01	.10000E+01	-1.888614	77.99	13798.30	0.565258
-0.02636	1.386	.10976E+01	.10000E+01	-1.932140	78.71	14559.32	0.548792
-0.02636	1.459	.10658E+01	.10000E+01	-1.973930	79.41	15320.34	0.532885
-0.02636	1.531	.10350E+01	.10000E+01	-2.014124	80.08	16081.35	0.517519
-0.02636	1.604	.10053E+01	.10000E+01	-2.052780	80.74	16842.37	0.502672
-0.02636	1.676	.97664E+00	.10000E+01	-2.090004	81.37	17603.39	0.488327
-0.02636	1.749	.94892E+00	.10000E+01	-2.125876	81.99	18364.41	0.474464
-0.02636	1.821	.92212E+00	.10000E+01	-2.160435	82.59	19125.42	0.461064
-0.02636	1.894	.89622E+00	.10000E+01	-2.193796	83.18	19886.44	0.448114
-0.02636	1.966	.87119E+00	.10000E+01	-2.225998	83.75	20647.46	0.435598
-0.02636	2.039	.84699E+00	.10000E+01	-2.257092	84.31	21408.48	0.423498
-0.02636	2.111	.82360E+00	.10000E+01	-2.287164	84.86	22169.49	0.411806

NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(N)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
-0.02636	2.184	.80079E+00	.10000E+01	-2.316205	85.39	22930.51	0.400500
-0.02636	2.256	.77913E+00	.10000E+01	-2.344278	85.92	23691.53	0.389569
-0.02636	2.329	.75800E+00	.10000E+01	-2.371427	86.43	24452.55	0.379002
-0.02636	2.401	.73754E+00	.10000E+01	-2.397687	86.93	25213.56	0.368784
-0.02636	2.473	.71778E+00	.10000E+01	-2.423035	87.43	25974.58	0.358894
-0.02636	2.546	.69867E+00	.10000E+01	-2.447593	87.91	26735.60	0.349336
-0.02636	2.618	.68017E+00	.10000E+01	-2.471349	88.39	27496.62	0.340091
-0.02636	2.691	.66229E+00	.10000E+01	-2.494335	88.86	28257.63	0.331149
-0.02636	2.763	.64501E+00	.10000E+01	-2.516629	89.32	29018.65	0.322510
-0.02636	2.836	.62829E+00	.10000E+01	-2.538170	89.77	29779.67	0.314148
-0.02636	2.908	.61211E+00	.10000E+01	-2.559016	90.22	30540.69	0.306059
-0.02636	2.981	.59646E+00	.10000E+01	-2.579194	90.66	31301.71	0.298234
-0.02636	3.053	.58132E+00	.10000E+01	-2.598725	91.09	32062.72	0.290665
-0.02636	3.126	.56665E+00	.10000E+01	-2.617551	91.51	32823.74	0.283327
-0.02636	3.198	.55247E+00	.10000E+01	-2.635818	91.93	33584.75	0.276238
-0.02636	3.271	.53875E+00	.10000E+01	-2.653486	92.35	34345.77	0.269376
-0.02636	3.343	.52547E+00	.10000E+01	-2.670577	92.75	35106.79	0.262736
-0.02636	3.416	.51264E+00	.10000E+01	-2.687179	93.16	35867.80	0.256324
-0.02636	3.488	.50021E+00	.10000E+01	-2.703185	93.55	36628.82	0.250107
-0.02636	3.560	.48818E+00	.10000E+01	-2.718669	93.94	37389.83	0.244091
-0.02636	3.633	.47653E+00	.10000E+01	-2.733646	94.33	38150.85	0.238270
-0.02636	3.705	.46526E+00	.10000E+01	-2.748125	94.71	38911.86	0.232632
-0.02636	3.778	.45432E+00	.10000E+01	-2.762038	95.08	39672.88	0.227162
-0.02636	3.850	.44375E+00	.10000E+01	-2.775547	95.45	40433.69	0.221876
-0.02636	3.923	.43351E+00	.10000E+01	-2.788594	95.81	41194.91	0.216757
-0.02636	3.995	.42360E+00	.10000E+01	-2.801195	96.17	41955.93	0.211800
-0.02636	4.068	.41403E+00	.10000E+01	-2.813448	96.53	42716.94	0.207016
-0.02636	4.140	.40473E+00	.10000E+01	-2.825217	96.88	43477.96	0.202369
-0.02636	4.213	.39574E+00	.10000E+01	-2.836589	97.23	44238.97	0.197871
-0.02636	4.285	.38703E+00	.10000E+01	-2.847566	97.57	44999.99	0.193516

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VERSION DATE      = : 05/12/83
DATA FILE         = : seawat.dat
GRAPH ? (Y/N)     = : n
NUMBER OF POINTS  =   60
DISTANCE          =    45.00
STARTING POINT    =     0.10
TRANSMITTER HEIGHT=     0.00
RECEIVER HEIGHT   =     0.00
FREQUENCY         =    25.40
NUMBER OF LAYERS  =   0
NUMBER OF RUNS    =   6
  REL. PERM. (BOTTOM)=  75.6100
       COND. (BOTTOM)=   2.8460
         NORMALIZED SURFACE IMPEDENCE = 0.0160354 + 0.0154371 i
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NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(N)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
-0.03802	0.013	.19810E+01	.10000E+01	-0.203588	30.32	100.00	0.990534
-0.03802	0.113	.18840E+01	.10000E+01	-0.592389	49.46	861.02	0.942017
-0.03802	0.214	.17980E+01	.10000E+01	-0.808063	55.36	1622.03	0.899039
-0.03802	0.314	.17180E+01	.10000E+01	-0.973728	59.10	2383.05	0.859025
-0.03802	0.414	.16428E+01	.10000E+01	-1.112064	61.90	3144.07	0.821393
-0.03802	0.515	.15717E+01	.10000E+01	-1.232370	64.16	3905.09	0.785842
-0.03802	0.615	.15043E+01	.10000E+01	-1.339548	66.09	4666.10	0.752189
-0.03802	0.715	.14405E+01	.10000E+01	-1.436572	67.78	5427.12	0.720253
-0.03802	0.815	.13799E+01	.10000E+01	-1.525380	69.29	6188.14	0.689946
-0.03802	0.916	.13223E+01	.10000E+01	-1.607376	70.67	6949.15	0.661145
-0.03802	1.016	.12675E+01	.10000E+01	-1.683586	71.94	7710.17	0.633757
-0.03802	1.116	.12154E+01	.10000E+01	-1.754756	73.12	8471.19	0.607706
-0.03802	1.217	.11658E+01	.10000E+01	-1.821503	74.23	9232.20	0.582912
-0.03802	1.317	.11186E+01	.10000E+01	-1.884274	75.28	9993.22	0.559310
-0.03802	1.417	.10736E+01	.10000E+01	-1.943512	76.27	10754.24	0.536832
-0.03802	1.517	.10308E+01	.10000E+01	-1.999550	77.22	11515.25	0.515418
-0.03802	1.618	.99001E+00	.10000E+01	-2.052634	78.13	12276.27	0.495016
-0.03802	1.718	.95113E+00	.10000E+01	-2.103012	79.00	13037.29	0.475572
-0.03802	1.818	.91406E+00	.10000E+01	-2.150857	79.83	13798.30	0.457036
-0.03802	1.919	.87871E+00	.10000E+01	-2.196387	80.64	14559.32	0.439364
-0.03802	2.019	.84501E+00	.10000E+01	-2.239738	81.43	15320.34	0.422512
-0.03802	2.119	.81287E+00	.10000E+01	-2.281086	82.18	16081.35	0.406442
-0.03802	2.220	.78221E+00	.10000E+01	-2.320498	82.92	16842.37	0.391112
-0.03802	2.320	.75296E+00	.10000E+01	-2.358109	83.63	17603.39	0.376487
-0.03802	2.420	.72504E+00	.10000E+01	-2.393969	84.33	18364.41	0.362528
-0.03802	2.520	.69840E+00	.10000E+01	-2.428236	85.01	19125.42	0.349208
-0.03802	2.621	.67298E+00	.10000E+01	-2.460961	85.67	19886.44	0.336495
-0.03802	2.721	.64870E+00	.10000E+01	-2.492212	86.31	20647.46	0.324357
-0.03802	2.821	.62553E+00	.10000E+01	-2.522149	86.94	21408.48	0.312779
-0.03802	2.922	.60342E+00	.10000E+01	-2.550709	87.56	22169.49	0.301718

NUMERICAL DISTANCE PHASE (RAD)	MAGNTD	ELECTRIC FIELD MAGNTD	FACTOR	PHASE	LOSS (DB)	DISTANCE (METERS)	MAGNITUDE OF F(N)
-0.03802	3.022	.58230E+00	.10000E+01	-2.578006	88.16	22930.51	0.291156
-0.03802	3.122	.56211E+00	.10000E+01	-2.604011	88.75	23691.53	0.281058
-0.03802	3.222	.54283E+00	.10000E+01	-2.628901	89.33	24452.55	0.271419
-0.03802	3.323	.52441E+00	.10000E+01	-2.652668	89.90	25213.56	0.262207
-0.03802	3.423	.50682E+00	.10000E+01	-2.675441	90.45	25974.58	0.253415
-0.03802	3.523	.49001E+00	.10000E+01	-2.697145	91.00	26735.60	0.245009
-0.03802	3.624	.47394E+00	.10000E+01	-2.717867	91.53	27496.62	0.236974
-0.03802	3.724	.45856E+00	.10000E+01	-2.737571	92.05	28257.63	0.229284
-0.03802	3.824	.44386E+00	.10000E+01	-2.756413	92.57	29018.65	0.221936
-0.03802	3.924	.42981E+00	.10000E+01	-2.774375	93.07	29779.67	0.214909
-0.03802	4.025	.41637E+00	.10000E+01	-2.791498	93.57	30540.69	0.208190
-0.03802	4.125	.40353E+00	.10000E+01	-2.807934	94.05	31301.71	0.201777
-0.03802	4.225	.39125E+00	.10000E+01	-2.823509	94.53	32062.72	0.195628
-0.03802	4.326	.37950E+00	.10000E+01	-2.838372	95.00	32823.74	0.189754
-0.03802	4.426	.36822E+00	.10000E+01	-2.852393	95.46	33584.75	0.184113
-0.03802	4.526	.35742E+00	.10000E+01	-2.865780	95.91	34345.77	0.178713
-0.03802	4.626	.34712E+00	.10000E+01	-2.878535	96.36	35106.79	0.173561
-0.03802	4.727	.33727E+00	.10000E+01	-2.890795	96.79	35867.80	0.168640
-0.03802	4.827	.32780E+00	.10000E+01	-2.902335	97.22	36628.82	0.163903
-0.03802	4.927	.31872E+00	.10000E+01	-2.913291	97.64	37389.83	0.159365
-0.03802	5.028	.31006E+00	.10000E+01	-2.923752	98.06	38150.85	0.155033
-0.03802	5.128	.30170E+00	.10000E+01	-2.933490	98.47	38911.86	0.150853
-0.03802	5.228	.29368E+00	.10000E+01	-2.942788	98.87	39672.88	0.146843
-0.03802	5.328	.28605E+00	.10000E+01	-2.951658	99.26	40433.89	0.143027
-0.03802	5.429	.27871E+00	.10000E+01	-2.960185	99.65	41194.91	0.139357
-0.03802	5.529	.27168E+00	.10000E+01	-2.968188	100.03	41955.93	0.135844
-0.03802	5.629	.26495E+00	.10000E+01	-2.975715	100.41	42716.94	0.132478
-0.03802	5.730	.25844E+00	.10000E+01	-2.982872	100.78	43477.96	0.129221
-0.03802	5.830	.25218E+00	.10000E+01	-2.989469	101.14	44238.97	0.126091
-0.03802	5.930	.24623E+00	.10000E+01	-2.995856	101.49	44999.99	0.123119

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VERSION DATE      = ! 05/12/83
DATA FILE         = ! seaust.dat
GRAPH ? (Y/N)     = ! n
NUMBER OF POINTS  =   60
DISTANCE          =    45.00
STARTING POINT    =     0.10
TRANSMITTER HEIGHT=     0.00
RECEIVER HEIGHT   =     0.00
FREQUENCY         =    25.40
NUMBER OF LAYERS  =    0
NUMBER OF RUNS    =    6
  REL. PERM. (BOTTOM)=  77.1600
       COND. (BOTTOM)=   2.2900
         NORMALIZED SURFACE IMPEDENCE = 0.0179239 + 0.0170834 i
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NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(N)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
-0.04801	0.016	.19753E+01	.10000E+01	-0.226385	30.34	100.00	0.987667
-0.04801	0.140	.18542E+01	.10000E+01	-0.657312	49.59	861.02	0.927124
-0.04801	0.265	.17493E+01	.10000E+01	-0.895142	55.60	1622.03	0.874661
-0.04801	0.389	.16531E+01	.10000E+01	-1.076973	59.43	2383.05	0.826569
-0.04801	0.513	.15639E+01	.10000E+01	-1.228103	62.32	3144.07	0.781960
-0.04801	0.637	.14807E+01	.10000E+01	-1.358906	64.68	3905.09	0.740372
-0.04801	0.761	.14029E+01	.10000E+01	-1.474853	66.70	4666.10	0.701492
-0.04801	0.885	.13301E+01	.10000E+01	-1.579276	68.47	5427.12	0.665071
-0.04801	1.009	.12618E+01	.10000E+01	-1.674385	70.07	6188.14	0.630904
-0.04801	1.133	.11976E+01	.10000E+01	-1.761709	71.53	6949.15	0.598825
-0.04801	1.257	.11373E+01	.10000E+01	-1.842373	72.88	7710.17	0.568685
-0.04801	1.381	.10807E+01	.10000E+01	-1.917266	74.14	8471.19	0.540343
-0.04801	1.506	.10273E+01	.10000E+01	-1.987055	75.33	9232.20	0.513679
-0.04801	1.630	.97713E+00	.10000E+01	-2.052342	76.45	9993.22	0.488580
-0.04801	1.754	.92987E+00	.10000E+01	-2.113509	77.52	10754.24	0.464948
-0.04801	1.878	.88535E+00	.10000E+01	-2.170908	78.54	11515.25	0.442688
-0.04801	2.002	.84340E+00	.10000E+01	-2.224909	79.52	12276.27	0.421711
-0.04801	2.126	.80386E+00	.10000E+01	-2.275803	80.46	13037.29	0.401940
-0.04801	2.250	.76657E+00	.10000E+01	-2.323768	81.36	13798.30	0.383299
-0.04801	2.374	.73141E+00	.10000E+01	-2.369035	82.24	14559.32	0.365718
-0.04801	2.498	.69824E+00	.10000E+01	-2.411709	83.08	15320.34	0.349129
-0.04801	2.623	.66694E+00	.10000E+01	-2.452046	83.90	16081.35	0.333478
-0.04801	2.747	.63740E+00	.10000E+01	-2.490211	84.70	16842.37	0.318710
-0.04801	2.871	.60951E+00	.10000E+01	-2.526249	85.47	17603.39	0.304764
-0.04801	2.995	.58318E+00	.10000E+01	-2.560323	86.22	18364.41	0.291598
-0.04801	3.119	.55830E+00	.10000E+01	-2.592448	86.95	19125.42	0.279156
-0.04801	3.243	.53479E+00	.10000E+01	-2.622846	87.66	19886.44	0.267405
-0.04801	3.367	.51258E+00	.10000E+01	-2.651546	88.36	20647.46	0.256297
-0.04801	3.491	.49160E+00	.10000E+01	-2.678767	89.04	21408.48	0.245808
-0.04801	3.615	.47176E+00	.10000E+01	-2.704412	89.70	22169.49	0.235885

NUMERICAL DISTANCE PHASE (RAD)	DISTANCE MAGNTD	ELECTRIC FIELD MAGNTD	FACTOR	PHASE	LOSS (DB)	DISTANCE (METERS)	MAGNITUDE OF F(N)
-0.04801	3.740	.45299E+00	.10000E+01	-2.728545	90.34	22930.51	0.226501
-0.04801	3.864	.43523E+00	.10000E+01	-2.751348	90.97	23691.53	0.217624
-0.04801	3.988	.41843E+00	.10000E+01	-2.772836	91.57	24452.55	0.209220
-0.04801	4.112	.40255E+00	.10000E+01	-2.793215	92.19	25213.56	0.201283
-0.04801	4.236	.38750E+00	.10000E+01	-2.812335	92.78	25974.58	0.193755
-0.04801	4.360	.37326E+00	.10000E+01	-2.830361	93.36	26735.60	0.186634
-0.04801	4.484	.35975E+00	.10000E+01	-2.847177	93.92	27496.62	0.179879
-0.04801	4.608	.34696E+00	.10000E+01	-2.863059	94.47	28257.63	0.173484
-0.04801	4.732	.33485E+00	.10000E+01	-2.878110	95.01	29018.65	0.167429
-0.04801	4.856	.32336E+00	.10000E+01	-2.892177	95.54	29779.67	0.161684
-0.04801	4.981	.31246E+00	.10000E+01	-2.905407	96.06	30540.69	0.156235
-0.04801	5.105	.30210E+00	.10000E+01	-2.917624	96.57	31301.71	0.151055
-0.04801	5.229	.29230E+00	.10000E+01	-2.929209	97.06	32062.72	0.146157
-0.04801	5.353	.28296E+00	.10000E+01	-2.939983	97.55	32823.74	0.141486
-0.04801	5.477	.27409E+00	.10000E+01	-2.950270	98.02	33584.75	0.137051
-0.04801	5.601	.26566E+00	.10000E+01	-2.959743	98.49	34345.77	0.132832
-0.04801	5.725	.25771E+00	.10000E+01	-2.968719	98.94	35106.79	0.128857
-0.04801	5.849	.25011E+00	.10000E+01	-2.976870	99.39	35867.80	0.125059
-0.04801	5.973	.24283E+00	.10000E+01	-2.984565	99.83	36628.82	0.121421
-0.04801	6.098	.23594E+00	.10000E+01	-2.991686	100.26	37389.83	0.117975
-0.04801	6.222	.22941E+00	.10000E+01	-2.998683	100.68	38150.85	0.114710
-0.04801	6.346	.22306E+00	.10000E+01	-3.004946	101.09	38911.86	0.111533
-0.04801	6.470	.21717E+00	.10000E+01	-3.010662	101.49	39672.88	0.108586
-0.04801	6.594	.21143E+00	.10000E+01	-3.015861	101.89	40433.89	0.105716
-0.04801	6.718	.20607E+00	.10000E+01	-3.021109	102.27	41194.91	0.103040
-0.04801	6.842	.20093E+00	.10000E+01	-3.026045	102.65	41955.93	0.100467
-0.04801	6.966	.19601E+00	.10000E+01	-3.030921	103.02	42716.94	0.098008
-0.04801	7.090	.19120E+00	.10000E+01	-3.034561	103.39	43477.96	0.095603
-0.04801	7.214	.18660E+00	.10000E+01	-3.037916	103.76	44238.97	0.093300
-0.04801	7.339	.18241E+00	.10000E+01	-3.041323	104.10	44999.99	0.091208

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VERSION DATE      = : 05/12/83
DATA FILE         = : seawat.dat
GRAPH ? (Y/N)     = : n
NUMBER OF POINTS  =   60
DISTANCE          =    45.00
STARTING POINT    =     0.10
TRANSMITTER HEIGHT=     0.00
RECEIVER HEIGHT   =     0.00
FREQUENCY         =    25.40
NUMBER OF LAYERS  =   0
NUMBER OF RUNS    =   6
  REL. PERM. (BOTTOM)=  80.2600
       COND. (BOTTOM)=   1.2040
    NORMALIZED SURFACE IMPEDENCE = 0.0252728 + 0.0229773 i
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NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(N)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
-0.09508	0.031	.19445E+01	.10000E+01	-0.311326	30.48	100.00	0.972364
-0.09508	0.267	.17118E+01	.10000E+01	-0.894036	50.29	861.02	0.855904
-0.09508	0.503	.15288E+01	.10000E+01	-1.207247	56.77	1622.03	0.764499
-0.09508	0.740	.13727E+01	.10000E+01	-1.440935	61.05	2383.05	0.686401
-0.09508	0.976	.12368E+01	.10000E+01	-1.630373	64.36	3144.07	0.618491
-0.09508	1.212	.11177E+01	.10000E+01	-1.790117	67.12	3905.09	0.558925
-0.09508	1.448	.10127E+01	.10000E+01	-1.927858	69.53	4666.10	0.506422
-0.09508	1.684	.91979E+00	.10000E+01	-2.048401	71.68	5427.12	0.459945
-0.09508	1.920	.83735E+00	.10000E+01	-2.154811	73.63	6188.14	0.418720
-0.09508	2.156	.76402E+00	.10000E+01	-2.249407	75.43	6949.15	0.382051
-0.09508	2.393	.69869E+00	.10000E+01	-2.333842	77.11	7710.17	0.349383
-0.09508	2.629	.64043E+00	.10000E+01	-2.409327	78.69	8471.19	0.320248
-0.09508	2.865	.58832E+00	.10000E+01	-2.477083	80.17	9232.20	0.294192
-0.09508	3.101	.54172E+00	.10000E+01	-2.537809	81.58	9993.22	0.270889
-0.09508	3.337	.49996E+00	.10000E+01	-2.592284	82.91	10754.24	0.250007
-0.09508	3.573	.46245E+00	.10000E+01	-2.641254	84.18	11515.25	0.231251
-0.09508	3.810	.42880E+00	.10000E+01	-2.685034	85.39	12276.27	0.214425
-0.09508	4.046	.39853E+00	.10000E+01	-2.724211	86.55	13037.29	0.199286
-0.09508	4.282	.37121E+00	.10000E+01	-2.759430	87.66	13798.30	0.185627
-0.09508	4.518	.34663E+00	.10000E+01	-2.790679	88.72	14559.32	0.173333
-0.09508	4.754	.32440E+00	.10000E+01	-2.818682	89.74	15320.34	0.162217
-0.09508	4.990	.30427E+00	.10000E+01	-2.843544	90.72	16081.35	0.152149
-0.09508	5.227	.28611E+00	.10000E+01	-2.865562	91.65	16842.37	0.143069
-0.09508	5.463	.26954E+00	.10000E+01	-2.885144	92.56	17603.39	0.134782
-0.09508	5.699	.25450E+00	.10000E+01	-2.902561	93.42	18364.41	0.127266
-0.09508	5.935	.24088E+00	.10000E+01	-2.917802	94.25	19125.42	0.120451
-0.09508	6.171	.22837E+00	.10000E+01	-2.931399	95.06	19886.44	0.114197
-0.09508	6.407	.21698E+00	.10000E+01	-2.943598	95.83	20647.46	0.108503
-0.09508	6.643	.20659E+00	.10000E+01	-2.953895	96.57	21408.48	0.103306
-0.09508	6.880	.19704E+00	.10000E+01	-2.963353	97.28	22169.49	0.098530

NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(U)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
-0.09508	7.116	.18825E+00	.10000E+01	-2.971712	97.97	22930.51	0.094136
-0.09508	7.352	.18007E+00	.10000E+01	-2.978347	98.64	23691.53	0.090044
-0.09508	7.588	.17277E+00	.10000E+01	-2.985540	99.27	24452.55	0.086393
-0.09508	7.824	.16574E+00	.10000E+01	-2.989996	99.90	25213.56	0.082881
-0.09508	8.060	.15954E+00	.10000E+01	-2.994589	100.49	25974.58	0.079779
-0.09508	8.297	.15346E+00	.10000E+01	-2.997037	101.08	26735.60	0.076740
-0.09508	8.533	.14758E+00	.10000E+01	-3.003058	101.66	27496.62	0.073800
-0.09508	8.769	.14279E+00	.10000E+01	-3.009073	102.19	28257.63	0.071404
-0.09508	9.005	.13817E+00	.10000E+01	-3.009753	102.70	29018.65	0.069094
-0.09508	9.241	.13344E+00	.10000E+01	-3.017731	103.23	29779.67	0.066728
-0.09508	9.477	.13043E+00	.10000E+01	-3.022446	103.65	30540.69	0.065224
-0.09508	9.714	.12539E+00	.10000E+01	-3.012142	104.20	31301.71	0.062702
-0.09508	9.950	.12226E+00	.10000E+01	-3.031635	104.63	32062.72	0.061138
-0.09508	10.186	.11816E+00	.10000E+01	-3.023812	105.13	32823.74	0.059085
-0.09508	10.422	.11484E+00	.10000E+01	-3.024775	105.58	33584.75	0.057427
-0.09508	10.658	.11160E+00	.10000E+01	-3.026295	106.02	34345.77	0.055804
-0.09508	10.894	.10866E+00	.10000E+01	-3.027042	106.44	35106.79	0.054334
-0.09508	11.131	.10587E+00	.10000E+01	-3.027740	106.86	35867.80	0.052941
-0.09508	11.367	.10323E+00	.10000E+01	-3.028393	107.26	36628.82	0.051619
-0.09508	11.603	.10072E+00	.10000E+01	-3.029005	107.65	37389.83	0.050363
-0.09508	11.839	.98327E-01	.10000E+01	-3.029579	108.03	38150.85	0.049169
-0.09508	12.075	.96051E-01	.10000E+01	-3.030120	108.41	38911.86	0.048031
-0.09508	12.311	.93796E-01	.10000E+01	-3.031069	108.78	39672.88	0.046903
-0.09508	12.547	.91732E-01	.10000E+01	-3.031512	109.14	40433.89	0.045871
-0.09508	12.784	.89759E-01	.10000E+01	-3.031932	109.49	41194.91	0.044884
-0.09508	13.020	.87869E-01	.10000E+01	-3.032331	109.84	41955.93	0.043939
-0.09508	13.256	.86059E-01	.10000E+01	-3.032711	110.17	42716.94	0.043034
-0.09508	13.492	.84322E-01	.10000E+01	-3.033073	110.50	43477.96	0.042166
-0.09508	13.728	.82655E-01	.10000E+01	-3.033418	110.83	44238.97	0.041332
-0.09508	13.964	.81054E-01	.10000E+01	-3.033748	111.15	44999.99	0.040531

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VERSION DATE      = : 05/12/83
DATA FILE         = : seawat.dat
GRAPH ? (Y/N)     = : n
NUMBER OF POINTS  =   60
DISTANCE          =    45.00
STARTING POINT    =     0.10
TRANSMITTER HEIGHT=     0.00
RECEIVER HEIGHT   =     0.00
FREQUENCY         =    25.40
NUMBER OF LAYERS  =   0
NUMBER OF RUNS    =   6
  REL. PERM. (BOTTOM)=  81.8100
       COND. (BOTTOM)=   6.6570
         NORMALIZED SURFACE IMPEDENCE = 0.0352505 + 0.0295270 i
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NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(N)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
-0.17625	0.056	.18820E+01	.10000E+01	-0.415491	30.77	100.00	0.941343
-0.17625	0.484	.14753E+01	.10000E+01	-1.167453	51.58	861.02	0.737898
-0.17625	0.912	.12024E+01	.10000E+01	-1.550638	58.86	1622.03	0.601438
-0.17625	1.340	.99566E+00	.10000E+01	-1.822415	63.84	2383.05	0.498014
-0.17625	1.768	.83401E+00	.10000E+01	-2.031213	67.78	3144.07	0.417157
-0.17625	2.196	.70561E+00	.10000E+01	-2.197349	71.12	3905.09	0.352933
-0.17625	2.624	.60249E+00	.10000E+01	-2.331900	74.04	4666.10	0.301356
-0.17625	3.052	.51890E+00	.10000E+01	-2.441790	76.65	5427.12	0.259547
-0.17625	3.480	.45077E+00	.10000E+01	-2.531957	79.01	6188.14	0.225469
-0.17625	3.908	.39484E+00	.10000E+01	-2.606037	81.17	6949.15	0.197493
-0.17625	4.336	.34859E+00	.10000E+01	-2.666665	83.15	7710.17	0.174358
-0.17625	4.764	.31019E+00	.10000E+01	-2.716454	84.98	8471.19	0.155151
-0.17625	5.192	.27807E+00	.10000E+01	-2.757118	86.68	9232.20	0.139088
-0.17625	5.620	.25106E+00	.10000E+01	-2.790305	88.26	9993.22	0.125577
-0.17625	6.048	.22820E+00	.10000E+01	-2.817464	89.72	10754.24	0.114141
-0.17625	6.476	.20869E+00	.10000E+01	-2.839658	91.09	11515.25	0.104384
-0.17625	6.904	.19193E+00	.10000E+01	-2.857223	92.38	12276.27	0.096002
-0.17625	7.332	.17746E+00	.10000E+01	-2.872403	93.58	13037.29	0.088761
-0.17625	7.760	.16501E+00	.10000E+01	-2.883951	94.70	13798.30	0.082536
-0.17625	8.188	.15405E+00	.10000E+01	-2.892025	95.77	14559.32	0.077052
-0.17625	8.616	.14457E+00	.10000E+01	-2.894947	96.76	15320.34	0.072310
-0.17625	9.044	.13513E+00	.10000E+01	-2.909014	97.77	16081.35	0.067590
-0.17625	9.472	.12869E+00	.10000E+01	-2.910280	98.59	16842.37	0.064371
-0.17625	9.900	.12161E+00	.10000E+01	-2.894015	99.47	17603.39	0.060828
-0.17625	10.328	.11546E+00	.10000E+01	-2.926247	100.29	18364.41	0.057752
-0.17625	10.756	.10989E+00	.10000E+01	-2.928882	101.07	19125.42	0.054967
-0.17625	11.184	.10485E+00	.10000E+01	-2.931206	101.82	19886.44	0.052443
-0.17625	11.612	.10026E+00	.10000E+01	-2.933267	102.53	20647.46	0.050146
-0.17625	12.040	.95985E-01	.10000E+01	-2.935942	103.23	21408.48	0.048010
-0.17625	12.468	.92143E-01	.10000E+01	-2.937468	103.88	22169.49	0.046088

NUMERICAL PHASE (RAD)	DISTANCE MAGNTD	ELECTRIC FIELD MAGNTD	FACTOR	PHASE	LOSS (DB)	DISTANCE (METERS)	MAGNITUDE OF F(N)
-0.17625	12.896	.88600E-01	.10000E+01	-2.938055	104.52	22930.51	0.044316
-0.17625	13.324	.85322E-01	.10000E+01	-2.940122	105.13	23691.53	0.042677
-0.17625	13.753	.82281E-01	.10000E+01	-2.941283	105.72	24452.55	0.041156
-0.17625	14.181	.79452E-01	.10000E+01	-2.942351	106.29	25213.56	0.039741
-0.17625	14.609	.76812E-01	.10000E+01	-2.943336	106.84	25974.58	0.038420
-0.17625	15.037	.74344E-01	.10000E+01	-2.944247	107.37	26735.60	0.037186
-0.17625	15.465	.72031E-01	.10000E+01	-2.945093	107.89	27496.62	0.036029
-0.17625	15.893	.69814E-01	.10000E+01	-2.946406	108.40	28257.63	0.034920
-0.17625	16.321	.67775E-01	.10000E+01	-2.947088	108.89	29018.65	0.033900
-0.17625	16.749	.65853E-01	.10000E+01	-2.947728	109.36	29779.67	0.032938
-0.17625	17.177	.64037E-01	.10000E+01	-2.948329	109.83	30540.69	0.032030
-0.17625	17.605	.62319E-01	.10000E+01	-2.948896	110.28	31301.71	0.031171
-0.17625	18.033	.60691E-01	.10000E+01	-2.949431	110.71	32062.72	0.030357
-0.17625	18.461	.59147E-01	.10000E+01	-2.949936	111.14	32823.74	0.029584
-0.17625	18.889	.57679E-01	.10000E+01	-2.950414	111.56	33584.75	0.028850
-0.17625	19.317	.56283E-01	.10000E+01	-2.950867	111.97	34345.77	0.028152
-0.17625	19.745	.54953E-01	.10000E+01	-2.951297	112.37	35106.79	0.027487
-0.17625	20.173	.53685E-01	.10000E+01	-2.951706	112.75	35867.80	0.026852
-0.17625	20.601	.52474E-01	.10000E+01	-2.952094	113.14	36628.82	0.026247
-0.17625	21.029	.51317E-01	.10000E+01	-2.952464	113.51	37389.83	0.025668
-0.17625	21.457	.50210E-01	.10000E+01	-2.952816	113.87	38150.85	0.025114
-0.17625	21.885	.49150E-01	.10000E+01	-2.953153	114.23	38911.86	0.024584
-0.17625	22.313	.48133E-01	.10000E+01	-2.953475	114.58	39672.88	0.024076
-0.17625	22.741	.47158E-01	.10000E+01	-2.953783	114.92	40433.89	0.023588
-0.17625	23.169	.46222E-01	.10000E+01	-2.954077	115.26	41194.91	0.023120
-0.17625	23.597	.45323E-01	.10000E+01	-2.954359	115.59	41955.93	0.022670
-0.17625	24.025	.44457E-01	.10000E+01	-2.954629	115.91	42716.94	0.022237
-0.17625	24.453	.43625E-01	.10000E+01	-2.954889	116.23	43477.96	0.021820
-0.17625	24.881	.42823E-01	.10000E+01	-2.955139	116.54	44238.97	0.021419
-0.17625	25.309	.42050E-01	.10000E+01	-2.955378	116.85	44999.99	0.021033

```
VERSION DATE      = : 05/12/83
DATA FILE         = : seawat.dat
GRAPH ? (Y/N)     = : n
NUMBER OF POINTS  =   60
DISTANCE          =   45.00
STARTING POINT    =    0.10
TRANSMITTER HEIGHT=    0.00
RECEIVER HEIGHT   =    0.00
FREQUENCY         =   25.40
NUMBER OF LAYERS  =   0
NUMBER OF RUNS    =   6
 REL. PERM. (BOTTOM)=  83.3600
      COND. (BOTTOM)=   0.1077
        NORMALIZED SURFACE IMPEDENCE = 0.0869400 + 0.0339159 i
```

NUMERICAL DISTANCE		ELECTRIC FIELD			LOSS	DISTANCE	MAGNITUDE OF F(N)
PHASE (RAD)	MAGNTD	MAGNTD	FACTOR	PHASE	(DB)	(METERS)	
-0.82696	0.232	.13303E+01	.10000E+01	-0.711412	33.78	100.00	0.669450
-0.82696	1.995	.50911E+00	.10000E+01	-1.629362	60.82	861.02	0.256193
-0.82696	3.758	.29704E+00	.10000E+01	-1.911553	71.00	1622.03	0.149484
-0.82696	5.521	.20303E+00	.10000E+01	-2.046051	77.65	2383.05	0.102170
-0.82696	7.284	.15216E+00	.10000E+01	-2.119436	82.36	3144.07	0.076572
-0.82696	9.047	.12108E+00	.10000E+01	-2.164798	86.43	3905.09	0.060930
-0.82696	10.811	.10104E+00	.10000E+01	-2.198315	89.35	4666.10	0.050853
-0.82696	12.574	.85704E-01	.10000E+01	-2.217648	92.29	5427.12	0.043128
-0.82696	14.337	.74402E-01	.10000E+01	-2.231799	94.66	6188.14	0.037441
-0.82696	16.100	.65734E-01	.10000E+01	-2.242586	96.74	6949.15	0.033078
-0.82696	17.863	.58874E-01	.10000E+01	-2.251066	98.60	7710.17	0.029626
-0.82696	19.626	.53310E-01	.10000E+01	-2.257904	100.28	8471.19	0.026827
-0.82696	21.389	.48707E-01	.10000E+01	-2.263529	101.81	9232.20	0.024510
-0.82696	23.152	.44835E-01	.10000E+01	-2.268237	103.22	9993.22	0.022562
-0.82696	24.916	.41533E-01	.10000E+01	-2.272233	104.52	10754.24	0.020900
-0.82696	26.679	.38684E-01	.10000E+01	-2.275664	105.73	11515.25	0.019466
-0.82696	28.442	.36201E-01	.10000E+01	-2.278646	106.86	12276.27	0.018217
-0.82696	30.205	.34017E-01	.10000E+01	-2.281258	107.93	13037.29	0.017118
-0.82696	31.968	.32081E-01	.10000E+01	-2.283564	108.93	13798.30	0.016144
-0.82696	33.731	.30354E-01	.10000E+01	-2.285618	109.88	14559.32	0.015275
-0.82696	35.494	.28803E-01	.10000E+01	-2.287456	110.77	15320.34	0.014494
-0.82696	37.258	.27403E-01	.10000E+01	-2.289110	111.63	16081.35	0.013790
-0.82696	39.021	.26133E-01	.10000E+01	-2.290611	112.44	16842.37	0.013151
-0.82696	40.784	.24975E-01	.10000E+01	-2.291970	113.22	17603.39	0.012568
-0.82696	42.547	.23916E-01	.10000E+01	-2.293215	113.96	18364.41	0.012035
-0.82696	44.310	.22942E-01	.10000E+01	-2.294356	114.68	19125.42	0.011545
-0.82696	46.073	.22045E-01	.10000E+01	-2.295408	115.36	19886.44	0.011093
-0.82696	47.836	.21215E-01	.10000E+01	-2.296374	116.02	20647.46	0.010676
-0.82696	49.600	.20446E-01	.10000E+01	-2.297273	116.66	21408.48	0.010289
-0.82696	51.363	.19730E-01	.10000E+01	-2.298105	117.27	22169.49	0.009929

NUMERICAL DISTANCE PHASE (RAD)	MAGNTD	ELECTRIC FIELD MAGNTD	FACTOR	PHASE	LOSS (DB)	DISTANCE (METERS)	MAGNITUDE OF F(N)
-0.82696	53.126	.19063E-01	.10000E+01	-2.298085	117.86	22930.51	0.009593
-0.82696	54.889	.18439E-01	.10000E+01	-2.299607	118.43	23691.53	0.009279
-0.82696	56.652	.17855E-01	.10000E+01	-2.300287	118.99	24452.55	0.008985
-0.82696	58.415	.17307E-01	.10000E+01	-2.300919	119.53	25213.56	0.008709
-0.82696	60.178	.16791E-01	.10000E+01	-2.301516	120.05	25974.58	0.008450
-0.82696	61.942	.16306E-01	.10000E+01	-2.302080	120.55	26735.60	0.008205
-0.82696	63.705	.15847E-01	.10000E+01	-2.302609	121.04	27496.62	0.007975
-0.82696	65.468	.15414E-01	.10000E+01	-2.303110	121.52	28257.63	0.007756
-0.82696	67.231	.15003E-01	.10000E+01	-2.303583	121.99	29018.65	0.007550
-0.82696	68.994	.14614E-01	.10000E+01	-2.304026	122.44	29779.67	0.007354
-0.82696	70.757	.14245E-01	.10000E+01	-2.304451	122.88	30540.69	0.007168
-0.82696	72.520	.13895E-01	.10000E+01	-2.305357	123.31	31301.71	0.006992
-0.82696	74.284	.13560E-01	.10000E+01	-2.305912	123.73	32062.72	0.006824
-0.82696	76.047	.13242E-01	.10000E+01	-2.306246	124.14	32823.74	0.006663
-0.82696	77.810	.12938E-01	.10000E+01	-2.306566	124.54	33584.75	0.006510
-0.82696	79.573	.12647E-01	.10000E+01	-2.306876	124.93	34345.77	0.006364
-0.82696	81.336	.12370E-01	.10000E+01	-2.307168	125.32	35106.79	0.006225
-0.82696	83.099	.12104E-01	.10000E+01	-2.307446	125.69	35867.80	0.006091
-0.82696	84.862	.11850E-01	.10000E+01	-2.307718	126.06	36628.82	0.005963
-0.82696	86.626	.11606E-01	.10000E+01	-2.307976	126.42	37389.83	0.005840
-0.82696	88.389	.11371E-01	.10000E+01	-2.308223	126.77	38150.85	0.005722
-0.82696	90.152	.11146E-01	.10000E+01	-2.308462	127.12	38911.86	0.005609
-0.82696	91.915	.10930E-01	.10000E+01	-2.308693	127.45	39672.88	0.005500
-0.82696	93.678	.10722E-01	.10000E+01	-2.308913	127.79	40433.89	0.005396
-0.82696	95.441	.10522E-01	.10000E+01	-2.309126	128.11	41194.91	0.005295
-0.82696	97.204	.10329E-01	.10000E+01	-2.309329	128.43	41955.93	0.005198
-0.82696	98.967	.10143E-01	.10000E+01	-2.309531	128.75	42716.94	0.005104
-0.82696	100.731	.99641E-02	.10000E+01	-2.309724	129.05	43477.96	0.005014
-0.82696	102.494	.97910E-02	.10000E+01	-2.309906	129.36	44238.97	0.004927
-0.82696	104.257	.96238E-02	.10000E+01	-2.310086	129.65	44999.99	0.004843

APPENDIX C
STATEMENT OF WORK FOR CONTRACT

CANADIAN HYDROGRAPHIC SERVICE
TIDAL INSTRUMENT DEVELOPMENT AND ENGINEERING SUPPORT
Bayfield Laboratory for Marine Science and Surveys
Burlington, Ontario L7R 4A6

STATEMENT OF WORK FOR:

RADAR PROPAGATION AND BACKSCATTERING PREDICTIONS

FOR CODAR SYSTEMS OPERATING IN BRACKISH WATERS

Introduction:

Coastal Ocean Dynamics Application Radar (CODAR) technology has potential for aiding Hydrographic surface current (water velocity) studies. The physics of the propagation and the backscattering mechanism from surface waves in coastal ocean areas and over/from sea ice have been well studied. The application to areas of Hydrographic interest in the Arctic (in summer) and at lower latitudes in the vicinity of significant fresh water discharge from rivers raises the question of the potential performance of the available technology with low conductivity water.

Action Items:

1. Examine and review the literature and data available to quantify the observed useful system range for current mapping of sea water.

2. Using the available theoretical models and the results of (1), predict the expected change in system performance due to increased propagation loss over brackish water as compared to sea water.

3. Apply the available models to predict the performance of the system for the remote sensing of estuarine fronts.

4. Apply the available models to predict the system performance for two Hydrographic current measurement scenarios (one Arctic, one coastal estuary).

Deliverables:

1. Six copies of the reports on Items 1-4, by 15 February, 1984.

POOR

QUALITY

ORIGINAL